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ERRATA

Page 11, line 32, read *found* instead of *hounded.*
,, 13, line 15, read *1903-1904* instead of *1904.*
,, 205, line 42, read *Metazoa* instead of *Metozoa.*
,, 228, line 5, read *two species* instead of *one form.*
228, *Bodo asiaticus* and *Heteromita zeylanica* should come below *Bodo urinarius*, and not in the Family Tetramitidæ
,, 232, read *Entamœba minuta* instead of *E. minutæ.*
,, 238, line 43, read *attached* instead of *attracted.*
,, 267, line 35, read *ingens* instead of *ingeus.*
,, 275, line 42, read *L. pycnosomæ* for *L. pyenosomæ.*
,, 275, line 43, read *Pycnosoma* for *Pyenosoma.*
,, 281, line 1, read *Leishmania infantum* for *Leishmania Infantum*
,, 289, line 33, read *Hæmamœbidæ*, instead of *Hæmomœbidæ.*
,, 331, in Figure 114, read *Bubali* instead of *Bubalis.*
,, 385, line 16, read *miller's* instead of *Miller's.*
,, 525, in Figure 224, read *Culicine* instead of *Culicæ.*
,, 689, line 9, read *Further* instead of *Farther.*
,, 697, line 14, read *Cantley* instead of *Cautley.*
,, 697, line 17, read *min. xxx* instead of *gr. xxx*
,, 704, in the small print at the bottom of the page, read *South America* instead of *South Africa.*
,, 704, second line of the footnote, read *Robledo* instead of *Robeledo.*
,, 722, line 17, read 103° F *or* 104° F. instead of 103° F *to* 104° F.
,, 725, line 11, read *Burma* instead of *Burmah.*
,, 745, line 5, read *Cercopithecus ruber* instead of *C. ruber*
,, 864, Plate V., read *Frambœsia Tropica* instead of *Frambœ Sia Tropica.*
,, 925, second footnote. read *Bodo asiaticus* for *Bodo zeylanicus*, and add *Heteromita zeylanica*, Castellani and Chalmers, 1910.
,, 1091, line 7, read *vaselini* ℥i. instead of *vaselini* ʒi.
,, 1134 in the footnote, read *folliclis* instead of *folliculitis.*
,, 1144 line 5, read *is generally incurable* instead of *is incurable.*

CASTELLANI & CHALMERS.

TROPICAL MEDICINE

MANUAL
OF
TROPICAL MEDICINE

BY

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COLLEGE; PATHOLOGIST, THE GENERAL HOSPITAL, COLOMBO; HOLT FELLOW
UNIVERSITY COLLEGE, LIVERPOOL, 1890; MEDICAL
OFFICER GOLD COAST COLONY,
1897-1901

UNIVERSITY SERIES

NEW YORK
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Dedication

TO

SIR PATRICK MANSON

K.C.M.G., M.D., LL.D., F.R.C.P., F.R.S.

THE FOUNDER OF SCIENTIFIC TROPICAL MEDICINE

PREFACE

THIS book is an attempt to describe the knowledge which we have found necessary to acquire and use during our work in Tropical Africa and Asia. We are well aware how difficult it is to discover one's own omissions and mistakes, and for such as may be found in this work we ask the indulgence of the reader.

An attempt has been made to keep the book as small as possible, but at the same time to describe, however briefly, the many subjects with which we have found it necessary to be acquainted. In order to attain this object, we have omitted all reference to practical laboratory methods, as such can readily be obtained in the excellent works of Daniels and Staunton, or Stephens and Christophers. Similarly, detailed descriptions of bacteria have not been included, as they are contained in anyof the modern textbooks on bacteriology, such as those by Muir and Ritchie, by Hewlett, or by Stitt, one of which should be in the possession of every practitioner working in the Tropics. Notwithstanding our desire for brevity, we have considered it advisable in a few instances to repeat our descriptions of parasites in the clinical portion of the work. This, however, has only been done when such descriptions were necessary, in order to give the reader a clear general account of the disease.

In the Clinical Section we have given importance to the descriptions of treatment, going into details, which some may think superfluous; but we know by experience that these details as regards dosage, modes of administration, etc., are required by the practitioner working in the Tropics, who often has no opportunity of consulting books on therapeutics and materia medica.

We desire to acknowledge gratefully the sympathy shown to us by the officials of the Colonial Office in London during the preparation of this work.

We are indebted to Sir Hugh Clifford, K.C.M.G., Sir Allan Perry, M.D., Dr. Sambon, Dr. Willey, Mr. Green, Miss Robertson, Mr. Barnard, Mr. Browning, and Mr. Drieberg for reading certain portions of the proofs, and for kindly lending us specimens and illustrations.

It gives us great pleasure to express our thanks to our artists, Mr. Terzi and Mr. M. J. de Silva, for the skill with which they have executed the drawings. Though a large number of these are original, still we have been compelled in order to illustrate the work fully to draw upon the generosity of a number of authors and publishers. We desire to state how much we are indebted to the kindness of these gentlemen in allowing us to redraw their originals —a task which has been performed as carefully as possible, and it is hoped that no error has in any way crept in.

It is our desire to acknowledge in the fullest manner the source of these copied drawings, and if any omission is found it is purely accidental. We are especially indebted to Professor Looss, of Cairo, who with the greatest generosity offered us his valuable original drawings of worms; to Professor Nuttall, many of whose drawings of mosquitoes and ticks have been used; to Mr. Austen and the Trustees of the British Museum for several illustrations of mosquitoes and flies; to Professor Ross for permission to copy certain drawings from the publications of the Liverpool School of Tropical Medicine; and to Professor R. Blanchard, Professor Hartmann, Professor Fülleborn, the Honourable Charles Rothschild, Dr. Lesage, Dr. Rodewald, and Dr. Neveu-Lemaire, for permission to use some of their valuable drawings.

We have also to thank Colonel Sir William Leishman, the Honourable Mr. Warren, C.M.G. (Surveyor-General of Ceylon), Professor Grassi, Dr. C. Mense, Colonel Giles, Captain Christophers, Captain Craig, Captain Patton, Mr. Fantham, and Mr. Dobell, for kind permission to utilize their illustrations.

We have also to acknowledge the kindness of the authorities of the Royal Society, and of the Hygiene Laboratory of the Public Health and Marine Hospital Service of the United States, as well as the Editors of the *Archiv für Schiffs- und Tropen-Hygiene*, of the *Lancet*, of the *British Medical Journal*, of the *Archiv für Protistenkunde*, of the *Quarterly Journal of the Microscopical Science*, of the *American Journal of Medical Sciences*, of the *Journal of Hygiene*, and of the *Journal of Parasitology*, in allowing us to copy certain prints.

Finally, we desire to acknowledge the constant kindness and courtesy of our publishers, Messrs. Baillière, Tindall, and Cox.

ALDO CASTELLANI.
ALBERT J. CHALMERS.

COLOMBO, CEYLON.
April, 1910.

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PART I

INTRODUCTORY

CHAPTER I

THE HISTORY OF TROPICAL MEDICINE

Primitive knowledge—Indian medicine—Egyptian medicine—Jewish medicine—Grecian medicine—Alexandrian medicine—Græco-Roman medicine—Arabian medicine—Modern medicine—Discovery of cinchona-bark—Beginnings of modern tropical medicine—Helminthology—The microscope—Bacteriology—Parasitic protozoa—Insects and disease—Poisons—Physical conditions—Unknown diseases—Cosmopolitan diseases—Schools of tropical medicine—Modern journals—References.

PRIMITIVE KNOWLEDGE.

Primitive peoples from the earliest times had some knowledge of medicine, but they did not understand the phenomena of disease, which they attributed to supernatural causes, generally to evil or offended spirits. Hence, in order to cure their ailments, it was natural that they should seek to propitiate these spirits; and accordingly we find that the medicine of primitive peoples was part of their religion, and was administered by their witch-doctors, fetish-men, and priests.

This primitive condition is still met with in many parts of the tropical world. Thus, on approaching a West African village, little images will be found on the roadside with offerings, which are often to make 'ju-ju' against some disease—*e.g.*, smallpox—which, in the guise of a malignant spirit, might otherwise enter the village.

Among native peoples will be found many curious medical, surgical, and obstetrical practices which are very interesting.

In Ceylon the superstitions are quite as elaborate as in West Africa, if not more so. Pestilences are considered to be punishments on the people for wickedness, and to be brought about by the conjunction of Saturn and Jupiter, or Saturn and Mars in Sagittarius.

Every illness is supposed to be due to a demon or to the 'evil eye,' and it is dangerous for a sick person to come in contact with an unclean person—the word 'unclean' being used in the Biblical sense—who is supposed to convey to the sick man a 'killa'—that is to say, a something which increases the severity of the illness. When a person is ill, every trivial incident becomes of importance, and is discussed seriously to discover whether it is a good or bad omen.

Another means of prognosis of great importance is the horoscope, which is generally made for the child soon after birth, and is written on a palm-leaf.

From it the influence of the planets with regard to good or evil on the individual can be calculated. If the influences of the planets are unfavourable, something can still be done by propitiatory means.

In times of pestilences, when the planets are contrary, the goddess Pattini can still intervene and avert the epidemic if proper devotion is paid to her.

Charms are used to drive out the evil spirit, or devil-dancing to shame or terrify him so that he may leave the body. Once out, amulets are used to prevent his re-entry, and 'pirit,' or the repetition of meritorious verses by priests, is also adopted.

Before any medicine can be administered, the position of the 'kalawa' or vital spot, must be ascertained. This spot moves all over the body in regular succession, occurring in different parts in different phases of the moon. Its position must be correctly calculated, and it will then be seen whether it is safe or otherwise to administer certain drugs. Another important matter is the constitution of the individual, whether it is inclined to be inflammatory or not, and the person must be dieted so as to counteract the baneful effects of the constitution.

During pregnancy care is taken with the diet and to avoid unpleasant maternal impressions, and many curious superstitions are connected with child-birth, such as passing the woman's body through a hoop in order to bring about an easy labour. Great fear is felt lest the severed cord should be drawn up into the uterus, and much good luck is associated with birth in a caul, or even with its possession.

Native peoples have generally a good knowledge of medical and poisonous plants growing in their vicinity, and it is well for the medical man living in the tropics to remember that cinchona-bark was originally simply a native Ecuador remedy, and that, therefore, it is not advisable to entirely despise popular drugs.

The earliest medicine, like that of certain races at the present time, must have been largely religious or theurgic, and hence very empirical. From this ancient condition many races—for example, the Chinese, Japanese, Aztecs, and Incas—developed a system of primitive medicine, but without any great result.

Two races, however, appear to have advanced far beyond this elementary stage, and to have laid the foundation upon which modern medicine has been built. These two races are the peoples of India and Egypt.

INDIAN MEDICINE.

In India there are signs of the existence of peoples among whom at a very early period a better race from the north-west forced its way. This race is often spoken of as the Aryan stock.

Their earliest literature appears to have been in the form of songs or hymns, and these were collected into what is called the Rîg-Veda.

Later, three more books called Samaveda, Ayurveda, and Atharvaveda were added, forming the Four Vedas. The word 'Veda' is said to be derived from the same root as the Latin *videre*, to see. The Vedas were said to be divinely inspired, and therefore to represent the wisdom of God.

The Ayurveda, or medical works, were believed to have originated directly from Brahma, who communicated them to Prajapati, his son, by whom they were passed to the Acwins, or sons of the sun, who in their turn gave them to Indra. Indra taught Bharadwaja, a learned sage, whose pupil, Agniveca, produced a work on the subject, which was subsequently edited and corrected by Charaka, whose name it bears, the true Ayurveda being destroyed.

Besides this ancient work, there is another, by Susruta, in which fevers are ascribed to the bites of mosquitoes. The age of these ancient books is quite unknown.

There is no doubt that the ancient doctors were well versed not merely in medicine and surgery, but in the prevention of disease and in operative midwifery. They apparently knew diabetes mellitus, dysentery, phthisis, syphilis, and diseases due to worms, etc. In diagnosis they paid great attention to the examination of the pulse, the temperature of the body, the colour of the skin, the urine, fæces, eye, voice, and the respiratory sounds. They possessed a remarkable symptomatology, and as regards treatment, divided diseases into incurable, which they refused to treat, and curable, which they treated according to a copious materia medica. Among the various remedies must be mentioned the fact that inoculation against smallpox was practised at the beginning of the warm season. Dietetics and toxicology were also well known.

Hospitals were founded by Buddhist princes in India and Ceylon. In fact, there is an account of a hospital being founded in Anurádhapura, the ancient capital of Ceylon, as early as the fifth century B.C., and later many more were established, as well as a sort of medical or sanitary department, having one medical officer to every ten villages, together with a definite sanitary organization, and with institutions for the reception of cripples, deformed, and poor persons. One of the Sinhalese kings appears to have known and practised medicine himself.

Unfortunately, caste distinctions became more rigid, and the Brahmans, fearing to touch blood or diseased matter, left the study of medicine to lower castes, and later, when the hospitals were closed, Indian medicine sank to a very low position, and did not again revive till the British Government founded its medical schools and research institutions. Moreover, the invasions of India by Mohammedans, and of Ceylon by Tamils, seem to have thoroughly upset all these excellent medical arrangements. The practitioner who works in India or Ceylon must not be surprised to find that the people strongly believe in their own system of medicine and medical men. At the same time, it must be remembered that their science and art is a great degeneration from the ancient Indian medicine.

Modern tropical medicine has now reached India and Ceylon from the West, and native medical men in increasing numbers are to be found trained in modern medicine and surgery. In other words, in these regions there have been three medical epochs—the first, in which there was great enlightenment and study; the second, in which the knowledge so acquired was largely lost; and the third, in which a revival of medical knowledge has come about by importation from the West.

EGYPTIAN MEDICINE.

In the meanwhile, and probably quite independently, medicine ad begun to be studied in Egypt ; for two papyri, one called the Ebers, or Leipzig Papyrus, of the sixteenth century B.C.—*i.e.*, about 550 B.C.—and the other the Berlin Papyrus, of the fourteenth entury B.C., have been found.

It seems probable that the Ebers Papyrus represents in writing he oldest Egyptian medicine, which previously had existed engraved n pillars of stone, ascribed to the god Thôt, who is regarded by nany experts as the Egyptian Æsculapius, though other authorities ssign this to Imhotep (meaning physician), whose temple was at Memphis. This Ebers Papyrus is a compilation written by several eople, one of whom appears to have been an oculist living in Byblos n Phœnicia. It is thought that it was written at On (Heliopolis), where medicine was taught by a kind of polyclinic. This papyrus ontains a great deal of medical knowledge, including remedies for iseases of the stomach, abdomen, and urinary bladder.

Directions for the removal of buboes and concerning diseases of he eyes and other sense-organs, nerves, heart, etc., are given. Further, it gives directions for getting rid of fleas and lice. It also ontains an account of a disease called ‘ A A A ’ and ‘ U H A,’ caused y a worm Heltu. The symptoms of the disease are described, nd a remedy is prescribed for the patient who has the worms n his abdomen. There is a difference of opinion as to what isease is referred to, and what kind or kinds of worms are meant. t is quite possible that it was not such a small worm as an gchylostome, but rather some other larger species—*e.g.*, an ascaris, r a tapeworm, or even an oxyuris, especially as these would be assed *per anum*, and would be easily seen. The ancient Egyptians re said not to have opened the bowels in embalming the body, hough they may have washed out the contents of the bowels, and hus have found the agchylostome.

The word ‘ A A T ’ in inscriptions on the temple of Denderah s said to refer to malaria. Egyptian medicine laid the foundations f Jewish and, in part, of Grecian medicine.

JEWISH MEDICINE.

The next clear reference to a tropical disease is to be found in the ible ; for in the Book of Numbers there is a description of a plague f fiery serpents, which quite possibly refers to the guinea-worm *Dracunculus medinensis*). Moreover, it appears as though Moses had aught the Israelites how to extract the worm by winding it round a iece of stick, as is done to-day in many parts of Africa. Further, he ppears to have made a model in brass of the method to be adopted —or, at all events, of the worm—in imitation of Egyptian customs.

Again, in the First Book of Samuel, chapters v. and vi., there is an account of a disease spreading among the inhabitants of the cities of Ashdod, Gath, Ekron, and Beth-shemesh, in which place no fewer than 50,070 men are said to have died. This disease was, without doubt, Oriental plague. The only point necessary in order to understand the reference is to remember that 'emerods' are buboes. It is, further, interesting to observe that these ancient people noted that the '*mice*' died and marred the land, showing that the plague affected both man and rat.

No one can fail to be impressed by the careful hygienic precautions of the Mosaic period. For example, consider how animals were divided into the clean and unclean, the reason for this being that the priests, in preparing them for sacrifice, noted the presence of parasites in the flesh of viscera of certain animals, which were therefore to be avoided.

It is true that the classification of disease was very simple—viz., into acute disorders, called 'plague'; and chronic disorders, with some sort of eruption, called 'leprosy'—but the extremely stringent quarantine rules very likely did a great deal of good, though doubtless very unkind to the unfortunate sufferer.

GRECIAN MEDICINE.

The next great work is that of Hippòcrates, who was supposed to be descended from Æsculapius, and who lived at Cos, and is said to have been born about 460 B.C. His forefathers appear to have been attached to this ancient temple of health, and there is no doubt that he himself practised in the Asclepion of Cos, of which an excellent account has recently been given by Caton.

The writings of Hippocrates, the most eminent of the eight physicians called by that name, are most interesting; for he clearly distinguished intermittent fevers from continuous fevers. Further, he recognized quotidian, tertian, and quartan fevers, and noted their frequency in summer and autumn, and their occurrence near stagnant water and after rains.

He also mentions relapsing fever, which, after his period, was forgotten till the eighteenth century.

When considering this advanced condition of Grecian medicine in the time of Hippocrates, it must be remembered that it probably owed much to Indian and Egyptian sources.

ALEXANDRIAN MEDICINE.

After the death of Alexander the Great, and the disruption of the Empire of Macedonia, medical science again went back to Egypt under the Ptolemies, and here in 170 B.C. Agatharchides described Dracunculus.

It is remarkable that this school was entirely influenced by Grecian, and not at all by Egyptian medicine. The period of the supremacy of Alexandrian medicine, however, did not last long.

GRÆCO-ROMAN MEDICINE.

After Alexandrian medicine came Græco-Roman medicine, largely derived directly from the Greek, for Roman medicine, until this influence came to be felt, was very primitive. Among the physicians of this period may be mentioned Themison of Laodicea (50 B.C.), who was the first to describe elephantiasis græcorum, or leprosy.

After him comes the great master of Roman medicine, Aulus Cornelius Celsus (25 B.C. to A.D. 45). It is quite possible that Celsus was not a medical man, but, whether or not, he has left behind him in his eight books of medicine a most valuable treatise. To him belongs the credit of clearly distinguishing two types of tertian malarial fever—viz., a simple and a much graver form. Hundreds of years later this was put upon a scientific basis by the researches of Marchiafava, Celli, and Bignami, in the same city (Rome). He also recognized the double quartan fever, and gave a description of elephantiasis, by which he meant leprosy.

After Celsus, medicine flourished in both the Eastern and the Western Empires. Among the many writers of this period, attention may be drawn to Aretæus of Cappadocia (A.D. 30-90), who describes dysentery, and gives a long account of elephantiasis.

Grecian medicine reaches its zenith in Galen, who was born at Pergamum A.D. 131, and died A.D. 210. He studied especially in Alexandria, and described carefully tertian and quartan malaria.

The next work which may be mentioned is the compilation of Paulus of Ægina, at the end of the seventh century A.D. This work gives a synopsis of medicine from the time of Galen up to nearly the end of the seventh century. In the second book considerable space is devoted to the malarial fevers, and there is also a section on 'Plague,' but what is meant by this is not certain, though Procopius, of the sixth century, is said to have written an account of glandular plague. There is also an article on siriasis, by which was meant an inflammation of the brain in young children. In the third book information is given concerning cholera, tenesmus, and dysentery.

His fourth book is particularly interesting, beginning with a description of elephantiasis græcorum, or leprosy. It contains an account of broad and round worms, especially ascarides and dracunculus, and further describes the bites of snakes, dogs, spiders, scorpions, centipedes, lizards, crocodiles, and other animals. There is also a description of the stings of wasps and bees, and an account of poisons.

ARABIAN MEDICINE.

After the fall of the Roman Empire, medical knowledge was kept alive by the Arabians from the eighth to the thirteenth century.

Among these may be mentioned Avicenna (Abu Ali el Hossein ebu Abdallah abu Sini, A.D. 980-1037), who gives an account of elephantiasis arabum under the term 'elephantia,' whereas he called elephantiasis græcorum 'juzam,' or 'judam,' which is interpreted into leprosy. He was also acquainted with intermittent fevers, as was also Rhazea, another celebrated physician.

Arabian medicine, carrying with it Greek medicine, was introduced into Spain, from whence it was reintroduced into Italy by the translation of Greek works from Arabic into Latin by scholars in Spain. This old learning in new form was particularly welcomed at the school of Salerno, which, indeed, alone had preserved some ideas of Greek medicine.

MODERN MEDICINE.

Later came the general revival of learning, and at the same time, as Payne so aptly puts it, the medical men of Western Europe were confronted with new diseases from the East, which came in epidemic form—*e.g.*, the plague and typhus. Indeed, it was during the study of syphilis that Girolamo Fracastori (1483-1553) first started modern epidemiology by formulating the theory of contagion.

DISCOVERY OF CINCHONA-BARK.

In the seventeenth century the epoch-making discovery of the value of cinchona-bark in the treatment of malarial fevers took place.

In 1638 the Countess of Chinchon, wife of the fourth Count, Viceroy of Peru, after nine years' residence in that country, was seized with tertian malarial fever. Don Lopez de Canizaries, the Corregidor of Loxa, hearing of this, sent her a parcel of the bark of a tree called by the Indians of Loxa 'quina-quina.' The duplication of the name of the tree is said to indicate that it has medical properties.

The value of this bark in the treatment of fever appears to have been only known locally, but was understood by the Spaniards in Loxa as far back as 1600. How the Indians became acquainted with the bark is not known, and the tales of the curing of their fevers by drinking the water of a lake into which a cinchona-tree had fallen, or of a sick puma chewing the bark, are considered to be myths invented later in Europe.

Dr. Don Juan de Vega administered the bark to the Countess, who quickly recovered, and four years later returned to Europe with a large supply of the bark, which she distributed to persons suffering from fever on her estates near Madrid. Hence the bark was often known as *Pulvis comitissæ*. In 1670 Jesuit missionaries sent some of the bark to Rome, from whence it was distributed throughout Europe by Cardinal de Lugo. Hence the names 'Jesuit's' or 'Cardinal's' bark.

Linnæus named the tree after the Countess, but spelt her name rongly, calling the tree *Cinchona officinalis.* A curious strife now se in Europe as to whether fever should be treated by bark or ot, but the labours of Morton and Sydenham, together with the ramatic cure of the Grand Dauphin, enabled its true value to be nown. The tree has since that time been introduced into several arts of the world, and grows well in India, Ceylon, and Java.

Morton, Sydenham, and Torti gave excellent clinical accounts of e fevers included under the term 'malaria,' the latter especially ealing with the pernicious fevers. In 1717 Lancisi appears to have reshadowed the discovery of the spread of the disease by mosuitoes, for he considered that marshes caused these fevers by their organic and organic emanations. In 1820 Pelletier and Caventou repared the alkaloid quinine from cinchona-bark.

BEGINNING OF MODERN TROPICAL MEDICINE.

HELMINTHOLOGY.

The foundation of modern tropical medicine may be said to have een laid when it was realized that parasites caused disease.

Worms, as has already been noticed, were known to the ancients n the shape of round and tape worms. Trematodes were first recogized by Jehan de Brie in the form of the liver-fluke in sheep, which vas afterwards described in 1547 by Gabucinus, the knowledge of hese animals being extended later by Leeuwenhoek (1675), Swammerdam (1752), Rosenhof (1758), Müller (1777), Zeder (1800), while n 1808 Rudolphi invented the word τρηματώδης, meaning 'pierced y holes,' for Zeder's sucking-worms. The knowledge of parasitic vorms has been greatly extended by the works of Dubini, the disoverer of the agchylostome, Cobbold, Von Siebold, Bilharz, Pruner, riesinger, Leuckart, Sonsino, Perroncito, and Braun. More reently by Looss, of Cairo; Low and Stiles, of the United States of merica; Von Linstow; Sambon and Leiper, of the London School of ropical Medicine; Ashburn, Craig, Musgrave, and other workers in he Philippine Islands; Railliet and Blanchard in Paris; Miura and Katsurada in Japan.

But among all these names connected with tropical helminthology hat of Sir Patrick Manson stands out pre-eminently first for the ar-reaching importance of his researches into filariasis. The etailed history of the discovery of *Filaria bancrofti* will be given ater; therefore it will suffice to state here that the microfilaria was iscovered by Demarquay, and that Lewis and Sonsino extended he knowledge of this discovery by finding the parasite in blood, vhile Bancroft found the adult in an abscess. Manson, in 1881, learly pointed out the connection between this worm and elephantiasis, and in 1882 demonstrated the extraordinary periodicity of the mbryo, which at that time was discredited by all to whom he escribed it.

Epoch-making in the history of tropical medicine was the discovery by Manson as far back as 1877, 1878, and 1879 of the different phases of the development of the embryo filaria in the mosquito, thus laying the foundation for the further discovery of the development of the malarial parasite in the Anopheles. From this time onwards Sir Patrick Manson interested himself in the development of knowledge concerning filaria. The result is that by the labours of Bancroft Low, Grassi, Noè, James, Daniels, Vincent, Annett, Dutton, Elliott, Ashburn, and Craig, a great mass of information has been collected. But the real credit for stimulating all this work lies with Sir Patrick Manson. In the meanwhile two other great workers appeared in the field of helminthology—viz., Looss of the Medical School of Cairo and Stiles of the United States—to both of whom tropical medicine is much indebted.

THE MICROSCOPE.

It must be clearly understood that the development of knowledge concerning the ætiology of disease depended very largely upon the evolution of the microscope. Until this was brought to such a condition of perfection that minute objects could be clearly and definitely seen, it was impossible for a human being to define the cause of any disease brought about by animals or plants as minute as parasitic protozoa and bacteria. Therefore, tropical medicine is indebted almost directly for many of its most important facts to the makers of achromatic and apochromatic lenses, for these alone have enabled the sciences of bacteriology and parasitic protozoology to be placed on a firm basis.

BACTERIOLOGY.

The next great factor in the knowledge of tropical disease has been bacteriology.

From the most remote times the suspicion that the mysterious cause of contagious and epidemic diseases must be sought in living entities has flashed through the minds of many observers. Columella, a contemporary of Seneca, records the belief, apparently popular in his time, of the living nature of miasmata and contagion. The idea of a *contagium vivum* was not extinguished even in the darkness of the Middle Ages. Thus, for instance, in a book written in the twelfth century by St. Hildegard, the abbess of a convent, we find notices of minute animals which produce disease.

In 1641 Athanasius Kircher, a friar, stated that he had observed minute living organisms in the blood of a patient during an epidemic of plague. But the first to promulgate scientifically a bacterial theory was Agostino Bassi, a country practitioner of the north of Italy in the early nineteenth century. At that time a peculiar disease was destroying the silkworms, bringing ruin to the country in which the silk industry was paramount. Bassi, by means of the microscope, discovered the germ which is the cause of the disease.

ıe organism received later the name of *Botritis bassiana.* From ıalogy, Bassi believed and stated that human diseases were also ıe to micro-organisms. Bassi's work was not appreciated by his ntemporaries, and failed to make any lasting impression.

Gruby, in 1844, showed that ringworm was due to a parasitic ngus ; Pollender, in 1849, and Davaine, in 1850, noted the *Bacillus ıthracis* in sheep's blood ; but it was not until after Pasteur, in 1857, ıd shown that fermentation was due to saccharomyces, and had ·scribed the bacillus of butyric acid fermentation, that Davaine, 1863, considered that the rodlets he had seen in sheep's blood ere the cause of the disease.

Then came Koch's epoch-making work, extending from 1877 to ıe present time, accounts of which can be found in any textbook bacteriology.

The important bacteria from a tropical medicine point of view ere discovered as follows :

Leprosy (Hansen)	1879.
Typhoid (Eberth)	1880.
Tetanus (Nicolaier)	1884.
Cholera (Koch)	1884.
Malta fever (Bruce)	1887.
Plague (Yersin and Kitasato)	1894.

The dysentery bacillus was found by Shiga in Japan (1898), and y Kruse in Germany (1900), the latter giving the more exact descrip- on of the germ.

The knowledge of the higher fungi causing tropical skin diseases ıd Madura-foot is largely due to Manson, Blanchard, Böllinger, rett, Ballingal, Eyre, Carter, Vincent, Nocard, Pinoy, and Brumpt.

PARASITIC PROTOZOA.

Protozoa were recognized by Leeuwenhoek in 1675, and the first fe-history of a protozoon (a vorticella) was worked out by Trembley ı 1744-47.

Among the protozoa parasitic in human beings, one of the first to e discovered was *Balantidium coli,* found by Malmsten of Stock- olm in the year 1856, and now known to be often associated with chronic catarrh and ulceration of the large bowel. *Lamblia intes- nalis,* discovered by Lambl in 1859, and *Trichomonas hominis,* ound by Davaine in 1864, are considered by many authors (Ebstein, tc.) to be the cause of certain cases of diarrhœa.

In 1875 an amœba was found by Lösch in St. Petersburg in a easant who suffered from an ulcerative inflammation of the large ıtestine, and Sonsino in Cairo also describes the finding of large umbers of amœbæ in the intestinal mucus of a child who had died f dysentery.

Other observers, however—*e.g.*, Grassi, Celli, and Cunningham—

found amœbæ in persons whose health had undergone no change. Kruse and Pasquale first suggested that there might be two species of amœbæ, one pathogenic, the other harmless. Later Schaudinn showed that there were two kinds of amœbæ affecting man—viz., *Entamœba coli* (Lösch), which was non-pathogenic; and *Entamœba histolytica*, described by himself, which was the cause of a certain kind of dysentery (amœbic dysentery) and of the abscess of the liver which at times followed it.

The discovery which has had the greatest influence on tropical medicine was that of the parasite of malarial fever by Laveran on November 6, 1880. True, this had to some extent been foreshadowed by Merkel in 1847, and Virchow in 1848, both of whom saw, and the latter figured, protoplasmic masses and pigment. Still, the entire credit for this great discovery is due to Laveran, for the others failed to recognize the parasitic nature of the forms they saw.

The development of our knowledge concerning this parasite is due to the valuable researches of Golgi, Marchiafava, Celli, Bignami, and many others. Of great importance was Golgi's discovery of the plurality of species of the malarial parasite.

Laveran's discovery and the work of his successors left, however, a great gap in the history of the parasite. They described lucidly its life-history in the human being, but could not explain how man became infected.

Sir Patrick Manson, reasoning on his work on the mosquito and filaria, suggested that there might be a stage of the development of the parasite in the mosquito. Working on Manson's theory, Ross, at that time in the Indian Medical Service, after years of patient hard work, was able to trace the full development of a bird's parasite in Culex, and partially that of the human parasite in the Anopheles, and thus made not merely a great discovery, but one which ought to be in time of lasting benefit to mankind. The full development of the human parasite was ~~hound~~found ed out by Grassi, who also showed that only Anopheles are capable of transmitting the parasite. Ross and Grassi's conclusions have been verified and extended by many people—*e.g.*, Marchiafava, Celli, Bignami, Dionisi, Daniels, Stephens, and Christophers, etc.—but the account of their work will be given later.

Thus, out of the fevers all classed as malaria, there issued a type clearly defined, to which the term 'malaria' must be restricted.

The discovery of the typhoid and paratyphoid germs and their allies differentiated another series of fevers from the chaotic collection of unclassified fevers called malaria.

In 1901 Forde and Dutton discovered a trypanosome, called by Dutton *Trypanosoma gambiense*, in a case of a peculiar irregular fever in the Gambia. In 1902 Dutton and Todd observed this organism in several other cases presenting the same type of fever, which became known at the time as trypanosome fever, Gambia fever, or Dutton's disease (Laveran and Mesnil). In 1902 and 1903 Castellani found the same organism in the cerebro-spinal fluid of cases of sleeping sickness, and first associated it with the ætiology. Further investigation by Bruce Nabarro and numerous observers in various regions of Africa showed that Gambia fever and sleeping sickness were two stages of the same disease. In 1903 Sambon and Brumpt independently promulgated the hypothesis that the human trypanosome was carried by a tsetse-fly, in all probability the *Glossina palpalis*; and Bruce and Nabarro experimentally proved that the *Trypanosome gambiense* is in reality introduced into human beings by the bite of *Glossina palpalis*. Bruce and others considered the transmission as purely mechanical, but the researches of Kleine show that the parasite undergoes true development in the body of the tsetse-fly. Chagas has recently discovered a new trypanosome in man in South America.

Trypanosomes were found in the lower animals long before they were discovered in man. Gruby first used (1844) the term 'trypanosoma' for a flagellate he had found in the blood of frogs in 1842. A similar parasite had been found by Valentin in 1841 in the common trout (*Salmo fario*). Very little progress was made in the investigations of these organisms until 1878, when Lewis, in India, described a trypanosome in the blood of rats, which was named by S. Kent *Trypanosoma lewisi*. In 1880 Evans discovered a trypanosome in animals affected with surra—*Trypanosoma evansi* (Steel, 1885). This was a most important discovery, as it showed that trypanosomes were capable of producing disease, while previously it had been believed that these parasites were harmless.

In 1894 Bruce discovered the Nagana trypanosome, *Trypanosoma brucei* (Plimmer and Bradford, 1899), and experimentally proved that the organism was conveyed by a species of tsetse-fly (*Glossina morsitans*). Rouget in the same year observed a trypanosome in the blood of horses affected with dourine—*Trypanosoma equiperdum* (Doflein 1901). Elmassian in 1901 described a trypanosome observed by him in mal de caderas—*Trypanosoma equinum* (Voges, 1901). Theiler, in 1902, in South Africa found a trypanosome in the blood of cattle affected with a peculiar disease known locally as '~~galziect~~é.' The parasite was named by Bruce *Trypanosoma theileri*.

Recently several other forms of trypanosomiasis have been described in the lower animals by Dutton and Todd, Cazalbou, Lingard, Ed. and Ét. Sergent, Shillong, Martini, Ziemann, and others.

In the meanwhile, Colonel Sir W. B. Leishman, in the year 1900, discovered some peculiar bodies in the spleen of a soldier who had died of what was called 'dum-dum fever,' but did not publish an account of his discovery till 1903, in which year Donovan also found the same parasitic bodies in Madras. This parasite was first considered to be a piroplasma by Laveran and Mesnil, and called *Piroplasma donovani*; but Ross created a new genus for it, using the term *Leishmania*. Wright of Boston found similar bodies in Oriental sore, which some regard as a localized and modified expression of the action of the parasite.

The knowledge of these bodies and the diseases they cause has been considerably extended by Christophers and by Martzmowsky and Bogroff, while a great advance was made by Rogers, who in 1904 showed that by artificial cultivation they developed into flagellate organisms. The life-history outside the human body has partially been traced by Captain Patton, of the Indian Medical Service, in the bed-bug.

In 1903 peculiar parasitic bodies, certainly protozoa, were discovered in rabies by Negri of Pavia. Negri's important discovery has been confirmed by many authors, and in the tropics by Cornwall.

In this section may be described the discovery of the causes of disease due to spirochætes, the nature and relationship of which are not yet clearly known.

Obermeyer, as far back as 1873, described the spirochæte of relapsing fever, which was thought to be spread by the bed-bug.

In 1904 Nabarro, Ross, and Milne, in Uganda discovered a spirochæte in the blood of persons suffering from tick fever—*i.e.*, a fever supposed to be due to the bite of *Ornithodoros moubata*—and independently in the same year Dutton and Todd, working in the Congo, described a spirochæte causing tick fever. This spirochæte has been proved by Breinl and Kinghorn to be distinct from the *Spirochæte recurrentis*, and in 1906 they gave it the name of *Spirochæta duttoni*, in honour of the late Dr. Dutton, of the Liverpool School, who had done so much for tropical medicine, and who himself had fallen a victim to this disease. Novy and Knapp had a little time previously assigned the names *Spirillum duttoni* to the same parasite. Other spirochætæ have recently been described, as will be mentioned later.

In 1905 the late Dr. Schaudinn discovered the presence of a spirochæte-like organism in syphilis, which he called *Spirochæta pallida*. Later he created for the organism a new genus—Treponema. In the same year Castellani demonstrated the presence of a spirochæte or treponema in yaws, and named it *Spirochæta pertenuis* (*Treponema pertenue*).

Reference must here be made to the discovery of a small protozoan parasite in sheep suffering from a disease called 'carceag' by Babes in Roumania in 1888. The name applied to this parasite —viz., hæmatococcus—could not be maintained, as it was already used in botany, hence the generic name of Babesia was given to the group by Starcovici in 1893. The term 'piroplasma,' so often used, was introduced by Patton in 1895.

It is, however, mostly due to the work of Smith and Kilborne on red-water in cattle that Babesia has become well known, together with the fact that it is spread by a tick.

The parasite *Babesia canis*, discovered by Piana and Galli Valerio in 1895, has been thoroughly described by Celli in 1900 and Nuttall in 1904, and the life-history in the tick has been worked out by Christophers. At the present time, thanks to the researches of Koch, Theiler, and others, several species of Babesia especially affecting cattle are known.

As to whether a Babesia is the cause of the tick or spotted fever of the Rocky Mountains appears open to grave doubt, although it has been described by Wilson and Chowning in 1902, and supported by Westbrook and Cobb in the same year, and Anderson in 1903, because other observers have failed to find any such organism. There is, however, strong evidence in favour of a tick being the spreader of the disease. We have already mentioned that the so-called Leishman-Donovan body (*Leishmania donovani*) was considered by Laveran and Mesnil to be a Babesia.

INSECTS AND DISEASE.

It will be obvious from the preceding section that ticks and insects play a great part in spreading protozoan diseases, and, further, it will be shown that they communicate bacterial disease as well.

Filaria can be spread by Culex, Stegomyia, or Anopheles ; malaria by several species of the Anophelinæ ; Babesia and spirochætes by ticks ; *Leishmania donovani* perhaps by bugs ; trypanosomes by tsetse-flies, and possibly by some kind of mosquitoes.

But apart from these diseases, of which we know the cause, there are two infections the unknown agent of which is carried by mosquitoes. Thus Finlay, in 1881, formulated definitely the hypothesis that yellow fever was spread by a mosquito, which in 1900 was proved by Reed, Carroll, Agramonte, and Lazear to be a fact, the mosquito being *Stegomyia fasciata*, now *Stegomyia calopus*.

With regard to dengue fever, Graham of Beirut, in 1903, thought that he had discovered a protozoon in the red corpuscles of persons suffering from the disease, and that this parasite underwent development in *Culex fatigans* (Wied). Doubt has been thrown upon Graham's parasite, but the idea that *Culex fatigans* (Wied) is responsible for the spread of dengue fever has been strongly supported by Ashburn and Craig in 1907.

Turning now to bacterial diseases, the work of the Indian Plague Committee, published in 1906-08, proves that the rat-flea (*Lœmopsylla cheopis*) is the main means of the spread of plague. With regard to typhoid, it was conclusively proved in the army concentration camps of the United States in the Spanish-American War of 1898 that flies were great spreaders of the disease, a fact already emphasized by Celli and others ; and this has been further supported by the work of Firth and Horrocks (1902), Chantemesse, and numerous other observers. Dysentery may also be spread by flies.

A knowledge, therefore, of ticks, biting flies, and other insects is of the greatest importance to the doctor who is to practise in the tropics. We refer the reader interested in this subject to the classical work of Nuttall on insects as carriers of disease in the Johns Hopkins Hospital Reports, 1899.

POISONS.

Micro-organisms are not the only causes of disease to be found in the tropics, for poisons from plants and animals are also of the greatest importance.

It has been shown that the most primitive peoples have definite knowledge of poisons, and it has already been mentioned how early the study of snake and other animal venoms began.

It will suffice here to indicate that the scientific study of snake-venom, begun by Prince Lucien Bonaparte in 1843, has been extended by Fayrer, Martin, Lamb, Calmette, and many others, and leave a fuller description of this and the history of other poisons to a later section.

PHYSICAL CONDITIONS.

Tropical medicine does not confine itself to diseases caused only by parasites and poisons, for there are such conditions as heat-stroke, which are entirely due to physical causes, and also there is the important question of the influence of tropical climates on man, which must be dealt with in a later chapter.

UNKNOWN DISEASES.

Notwithstanding all the rapid advance of knowledge in tropical diseases, there are many as yet unknown or little known diseases. The causation of blackwater fever, of yellow fever, of dengue, of sprue, of beri-beri, of ainhum, of goundou, and many others, still require explanation.

The method of infection with leprosy is still unknown, and it is quite likely that certain fevers are as yet undifferentiated.

COSMOPOLITAN DISEASES.

Though tropical medicine is limited to the description of certain diseases found mostly in the tropics, still there are many cosmopolitan diseases common to both temperate and tropical regions which must be mentioned in a work on tropical medicine.

SCHOOLS OF TROPICAL MEDICINE.

Nothing has done more to advance the knowledge of tropical medicine than the movement commenced by Sir Patrick Manson and the British Government in founding the London School of Tropical Medicine, and by Sir Alfred Jones and the citizens of Liverpool in founding the Liverpool School.

These, together with the schools in Paris, Hamburg, Lisbon, Naples, and elsewhere, have done a very great work. Previous to their foundation the medical man had to pick up his knowledge of tropical medicine as best he could.

It is not wise for a medical man, however well trained otherwise, to attempt to practise in the tropics without having gone through a course of instruction in one of these schools, for greatly will he regret his lack of special knowledge.

MODERN JOURNALS.

Unless the practitioner in the tropics keeps in touch with the work of the day, he will in a short time find himself deficient in much useful information.

The most valuable epitome of recent work is :

BALFOUR AND ARCHIBALD (1908). Review of Recent Advances in Tropical Medicine.

The progress of tropical medicine is to be found in the following journals :

American Tropical Diseases Society's Journal.
Annali di Medicina Navale (Roma).
Annual Reports of the Surgeons-General and Principal Civil Medical Officers of the British, French, and German Colonies.
Annals of Tropical Medicine and Parasitology (Liverpool).
Archivos de Hygiene et Pathologie Exoticas (Lisbon).
Archives de Parasitologie (Paris).
Archiv für Protistenkunde (Jena).
Archiv für Schiffs und Tropen hygiene (Leipzig), und die Beihefte (separate).
Atti della Società per gli studi della Malaria (Roma).
British Guiana Medical Journal (Demerara).
Bulletin de l'Institut Pasteur (Paris).
Bulletin de la Société de Pathologie Exotique (Paris).
Indian Medical Gazette (Calcutta).
Journal of Hygiene (Cambridge, England).
Journal of Parasitology (Cambridge).
Journal of the Royal Army Medical Corps (London).
Journal of Tropical Medicine (London).
Philippine Journal of Science (Manila).
Records of the Egyptian Government School of Medicine (Cairo).
Reports of the Advisory Committee for the Tropical Diseases Research Fund (London).
Scientific Memoirs by the Officers of the Medical and Sanitary Departments of India (Calcutta).
Studies from the Institute for Medical Research, Federated Malay States (London).
Transactions of the Society of Tropical Medicine and Hygiene (London).

Among the publications which at times have most valuable papers on tropical diseases and parasitology may be mentioned :

Arbeiten aus dem Kaiserlichen Gesundheitsamte.
British Medical Journal.
Bulletins and Reports of the following departments of the United States, Washington—(*a*) Animal Industry; (*b*) Public Health and Marine Hospital Service; (*c*) National Museum.
Centralblatt für Bakteriologie.
Deutsche Medizinische Wochenschrift.
Lancet.
Münchener Medizinische Wochenschrift.
Quarterly Journal of Microscopical Science.
Special Reports of the Royal Society.
Zeitschrift für Hygiene und Infectionen Krankheiten.

It will be obvious that unless a library is available—and there ought to be a well-equipped medical library in every colony and tropical State—it is extremely difficult for a medical man to keep abreast of the times.

If information with regard to diseases of animals is required other than that found in textbooks, the reader is referred to the *Journal of Tropical Veterinary Science*, Calcutta.

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CHAPTER II

TROPICAL CLIMATOLOGY

Tropical climates—Climatic factors—Temperature—Pressure—Winds—Humidity—Rainfall—Subdivisions of tropical climates—Psycho-physical aspect of climates.

TROPICAL CLIMATES.

CLIMATES may be classified, as suggested by Supan, according to temperature, into three groups :

1. Warm climates, extending from the Equator to the mean annual isotherm of 68° F.
2. Temperate climates, extending from the mean annual isotherm of 68° F. to that of 50° F. for the warmest months of the year.
3. Cold climates, lying polewards of the isotherm of 50° F. for the warmest months of the year.

Of these divisions, the warm climates alone concern us.

Warm or hot climates may be defined on a map of the world by the isotherms which represent a mean annual temperature of 68° F. or 20° C.

If now attention is turned to Fig. 1, it will be noticed that these isotherms are represented by irregular wavy lines situated about 35 degrees north latitude and rather less than 30 degrees south latitude.

This region is divided into two zones :

1. The Tropical Zone.
2. The Subtropical Zone.

1. **The Tropical Zone.**—The Tropical Zone is limited to the north and the south by the isotherm which represents a mean temperature for ' the coldest months of the year ' of 68° F. or 20° C.

It will be noticed that this isotherm corresponds more or less with 23½ degrees north or south latitude, which represent the Tropics of Cancer and Capricorn.

Examining the map a little more in detail, it will be noticed that, starting in the extreme west and travelling eastwards, the isotherm both north and south of the Equator is nearly the same as the latitude 23½ degrees north or south, but as the coast of America is

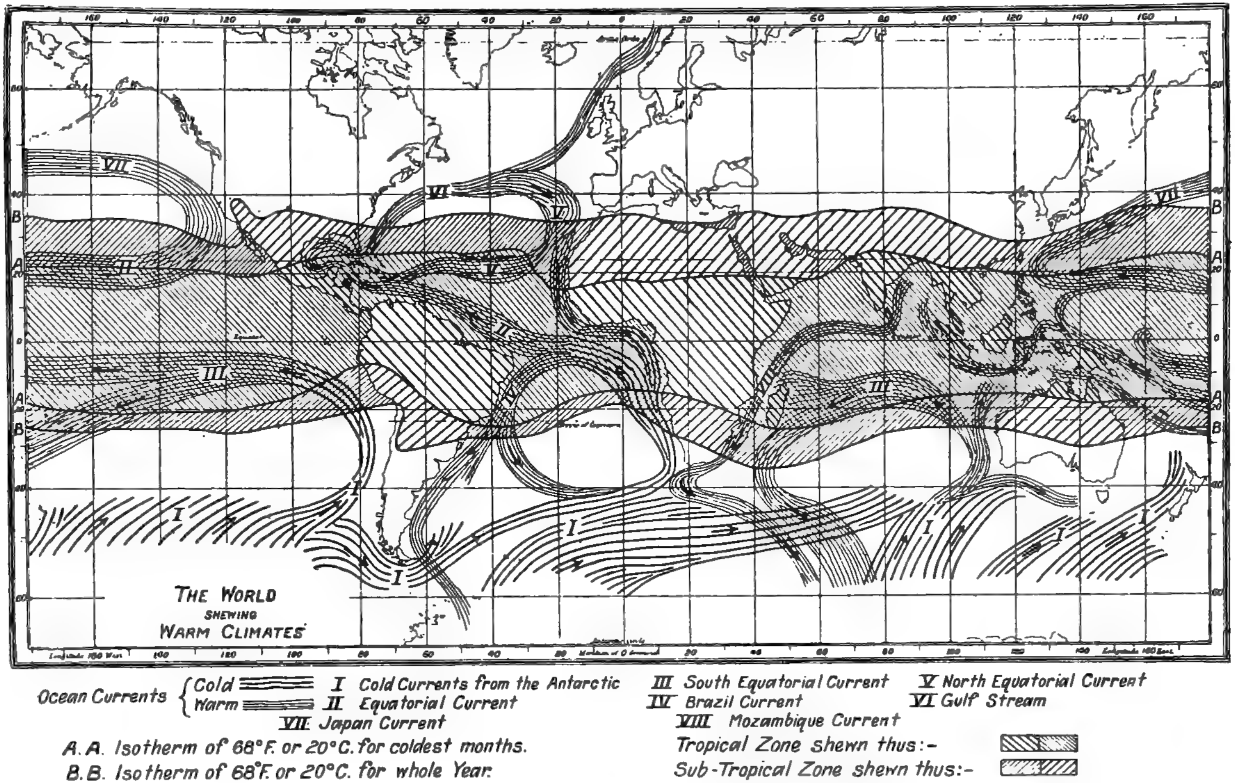
THE WORLD
SHEWING
WARM CLIMATES
Ocean Currents { Cold / Warm
I Cold Currents from the Antarctic
II Equatorial Current
III South Equatorial Current
IV Brazil Current
V North Equatorial Current
VI Gulf Stream
VII Japan Current
VIII Mozambique Current
A.A. Isotherm of 68°F. or 20°C. for coldest months.
B.B. Isotherm of 68°F. or 20°C. for whole Year.
Tropical Zone shewn thus:-
Sub-Tropical Zone shewn thus:-
A
B
I
II
III
V
VI
VII
Longitude 180 West
Longitude 180 East
Equator

FIG. 1.—THE WORLD, SHOWING WARM CLIMATES AS DELINEATED BY SUPAN'S LINES.

reached it dips a little to the south in the Northern Hemisphere, and considerably to the north in the Southern Hemisphere. This variation is caused by cold currents in the sea running along the west coast of America, the more important of which (marked I. on the map) is the cold current from the Antarctic.

Tracing the line farther eastward, it will be noticed that it rises towards the north in the Northern Hemisphere, and falls towards the south in the Southern Hemisphere. In the Northern Hemisphere this is due to the warm Equatorial Current (II.), and in the Southern Hemisphere to the warming effects of the land and to the warm Brazilian Current (IV.).

With reference to the different effect of land and sea, it is necessary to remember that though 25 per cent. of the heat of the sun's rays which fall on the outer limit of our atmosphere are absorbed, still these rays do not really warm the air to any appreciable extent. The real warmth of the air is obtained from the dark heat radiated from land and sea.

Land not only absorbs the radiant heat from the sun more quickly than water, but also more readily gives off the dark heat to the air; therefore the presence of a large area of land upon which the sun's rays fall more or less vertically at noon all the year round will raise the temperature of the air, and will tend to extend the area of the warm climates. Hence the land may become extremely hot—incredibly high temperatures have been mentioned by authors—while water never becomes very warm. The reason of this is that water, being a liquid, by convection and by currents tends to keep at a more even temperature than land, though, as already noted, the currents, cold and warm, have a marked influence on the climate.

Turning again to the map, and tracing the isotherm eastwards towards the west coast of Africa, it will be noticed that again both the northern and the southern isotherms approach the Equator, and again this is due to cold currents—in the north to the North Equatorial Current (V.), and in the south to the cold Antarctic Current (I.). Crossing the continent of Africa, the effect of land is seen, and on passing into the Indian Ocean the effect of the Mozambique and the South Equatorial Currents may be noted, and finally, to the west and east of Australia the cold Antarctic Currents produce effects.

Thus the Tropical Zone is alternately decreased and increased in area, the most marked diminutions being on the west coast of America and the west coast of Africa.

It will be observed that this zone includes Central America, a large portion of South America, the West Indies, a large portion of Africa, Madagascar, a portion of Arabia, India, Ceylon, Indo-China, Sumatra, Java, Borneo, the Philippine Islands, New Guinea, and a portion of Australia, and many other smaller islands.

2. **The Subtropical Zone.**—The Subtropical Zone lies between the isotherms of 68° F. (20° C.) for the temperature of the coldest month, and the same isotherms for the mean temperature of the year.

It is depicted in Fig. 1, and will be noticed to include a portion of North America and considerable portions of South America, Africa, Asia Minor, Arabia, Persia, North India, China, and Australia.

Another method of subdividing warm climates, based upon the winds and rainfall rather than upon the temperature, will be given at the end of this chapter.

CLIMATIC FACTORS.

Climate may be defined as the combined effects of the sun, the atmosphere, and the earth at any one place on the earth's surface.

The sun produces its influence by the heat, light, and chemical rays which issue from it.

The atmosphere acts by its chemical composition, its temperature and diathermancy, its humidity, pressure, motion (winds), and electrical conditions.

The earth's influence is due to latitude, relative proportion of land and water, ocean currents, soil, vegetation, configuration of the surface, and altitude.

In the present chapter the discussion on these factors may be grouped into the three headings of temperature, pressure, and humidity, leaving the chemical rays and their effects to the next chapter, while electrical conditions will be omitted.

Though we are compelled to deal in a cursory manner with these subjects, we would strongly advise the medical man about to practise in the tropics to make himself conversant with elementary meteorology, in order that he may understand the seasonal changes which will take place around him, and the data which he will obtain from meteorological instruments which may be in his charge. The latter especially applies to Government Medical Officers, who generally are responsible for a small meteorological station, often situate in the hospital compound.

TEMPERATURE.

Heat derived from the sun is capable of traversing the atmosphere surrounding the world, and thus reaching the earth, because this atmosphere is diathermanous to rays with short wave-lengths coming rom so hot a body as the sun. Dry air is diathermanous for all ays, but aqueous vapour is almost athermanous for infra-red rays, hough diathermanous for other rays.

In passing through the atmosphere, about 25 per cent. of the heat which has entered it is absorbed before it reaches sea-level.

The position of the sun is, however, of the utmost importance with regard to the quantity of heat reaching the earth. If the sun s quite vertical, probably only 20 per cent. is lost; whereas, if he beam is nearly horizontal, probably none reaches the earth.

The heat rays falling upon the earth are absorbed and converted nto dark heat—that is to say, into frequencies with longer wave-

TABLE A.

MEAN AND EXTREME AIR TEMPERATURE IN THE SHADE IN COLOMBO FOR THE YEAR 1905.

Month.	Mean.	9.30 a.m.	3.30 p.m.	Mean of Maximum.	Mean Daily Range.	Mean of Minimum.	Highest Maximum.		Absolute Range.	Lowest Minimum.	
							Date.	Degrees.		Date.	Degrees.
	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.	Degrees.			Degrees.		
January	79·2	81·2	84·1	86·8	14·6	72·2	26th	91·2	24·0	14th	67·2
February	80·1	81·8	85·4	87·4	14·4	73·0	13th	92·4	23·9	12th	68·5
March	83·1	85·2	87·6	89·3	12·7	76·6	6th	93·7	21·7	5th	72·0
April	81·9	83·6	85·3	87·8	11·1	76·7	3rd	91·7	18·1	9th	73·6
May	81·8	83·1	84·7	87·2	9·6	77·6	5th	89·4	15·6	24th	73·8
June	81·2	82·5	83·2	86·0	8·1	77·9	15th, 16th, & 17th	88·2	13·7	20th	74·5
July	82·1	83·2	84·6	86·4	7·8	78·6	8th, 28th, & 30th	87·4	10·9	19th	76·5
August	82·4	83·9	84·7	87·5	8·8	78·7	7th	89·0	12·5	22nd	76·5
September	81·0	82·9	83·8	86·1	9·9	76·2	3rd	88·4	15·2	6th	73·2
October	79·9	81·7	82·8	85·5	10·4	75·1	5th, 29th, & 30th	87·7	15·3	10th	72·4
November	80·8	82·3	85·1	87·4	12·3	75·1	6th	90·8	17·8	6th	73·0
December	79·8	81·1	85·2	88·2	15·0	73·2	23rd	91·7	23·2	30th	68·5
Year	81·1	82·6	84·7	87·1	11·2	75·9	March 6th	93·7	26·5	Jan. 14th	67·2
Means of extremes	—	—	—	—	—	—	—	90·2	17·7	—	72·5

lengths—and these are radiated back into the atmosphere (terrestrial radiation). This dark heat is absorbed by the atmosphere, which is, as already stated, almost athermanous to this kind of energy.

This atmospheric heat is one of the most important factors in determining the nature of a climate, and therefore requires a few remarks.

The following temperatures are usually recorded at meteorological stations:

1. Shade temperatures.
2. Solar radiation.
3. Terrestrial radiation.
4. Earth temperatures.

1. **Shade Temperature.**—The shade temperature of the air is measured by maximum and minimum thermometers. The figures in Table A, taken from the Ceylon meteorological reports, indicate how such records should be kept.

Altitude has a marked effect upon temperature, and must either be stated or else the temperature, for purposes of comparison, must be recorded in sea-level equivalents.

SEA-LEVEL EQUIVALENTS OF MONTHLY MEAN TEMPERATURE IN COLOMBO.

January	79·3	July	82·2
February	80·2	August	82·5
March	83·2	September	81·1
April	82·0	October	80·0
May	81·9	November	80·9
June	81·3	December	79·9

Average for 1905, 81·2.

These temperatures give a good idea of a tropical island climate. The extremes are neither very high nor irregular; the mean daily range of temperature throughout an average year is only 11·2° F., though it may be as much as 15·0° F.

Compare this with Jacobabad in Sind, North India, which may be taken as a type of a bad continental tropical station.

ELEVATION 186 FEET ABOVE SEA-LEVEL.

Month.	Mean.	Mean Maximum.	Mean Daily Range.	Mean Minimum.
January	57	74	31	43
February	62	77	29	48
March	74	90	30	60
April	83	99	31	68
May	91	108	32	76
June	96	111	28	83
July	94	107	24	83
August	91	103	22	81
September	88	101	25	76
October	78	96	33	63
November	65	84	34	50
December	58	75	32	43
Year	78	—	—	—

Mean highest temperature for the year, 118° F.
Mean lowest temperature for the year, 32° F.

EQUILIBRIUM TEMPERATURES OF SOLAR RADIATION IN COLOMBO.

Month.	Mean.	Maximum.		Minimum.		Difference, Sun and Shade.		
		Date.	Degrees.	Date.	Degrees.	Mean.	Maximum.	Minimum.
	Degrees.					Degrees	Degrees.	Degrees.
January	143·5	1st	150·7	12th	138·2	56·7	63·8	52·2
February	145·3	21st	156·2	9th	138·8	57·9	69·0	52·8
March	145·8	7th	154·0	1st	140·8	56·5	61·3	53·5
April	138·6	8th	152·8	13th	91·4	50·4	66·4	9·0
May	140·6	2nd	151·4	24th	92·8	53·4	67·2	9·3
June	138·3	18th	144·0	8th	115·5	52·3	57·8	32·8
July	140·8	22nd	145·5	12th	128·4	54·4	85·1	52·2
August	144·0	12th	153·5	18th	135·0	56·5	66·5	49·3
September	142·4	22nd	149·2	14th	111·0	56·3	62·8	29·8
October	140·3	9th	149·8	19th	94·8	54·8	62·2	14·2
November	142·5	9th	157·5	13th	115·8	55·1	69·3	28·8
December	142·6	4th	150·6	29th	122·8	54·4	63·2	38·8
Year	142·1	November 9th	157·5	April 13th	91·4	54·9	85·1	9·0
Means of extremes ..	—	—	151·3	—	118·8	—	65·4	35·2

TEMPERATURE OF TERRESTRIAL RADIATION IN 1905.

Month.	Mean.	Maximum.		Minimum.		Difference, Shade and Radiation.		
		Date.	Degrees.	Date.	Degrees.	Mean.	Maximum.	Minimum.
	Degrees.					Degrees.	Degrees.	Degrees.
January	68·7	6th	73·2	14th	61·5	3·5	5·7	1·3
February	70·1	24th	74·2	11th	64·0	2·9	5·8	0·3
March	73·3	30th	77·5	5th	67·0	3·3	8·0	2·0
April	74·9	6th	77·5	7th	71·8	1·8	5·6	0·5
May	75·7	21st	78·2	19th & 24th	73·0	1·9	4·4	0·5
June	75·6	2nd	77·5	20th	73·0	2·3	4·8	0·8
July	75·7	27th	78·0	1st	74·2	2·9	4·8	0·8
August	76·4	30th	78·0	22nd	74·8	2·3	3·5	1·4
September	74·4	1st	77·2	23rd	70·0	1·8	6·0	0·7
October	73·2	21st	75·2	10th	71·4	1·9	5·2	0·3
November	73·2	9th & 13th	76·0	6th	69·0	1·9	4·0	0·5
December	70·5	15th	74·2	30th	64·5	2·7	6·4	1·1
Year	73·5	May 21st	78·2	January 14th	61·5	2·4	8·0	0·5
Means of extremes ..	—	—	76·4	—	69·5	—	4·9	0·9

2. **Solar Radiation.**—Solar radiation is measured by black bulb and bright bulb thermometers *in vacuo*, mounted on posts 4 feet above the ground.

The former gives a higher temperature than the latter, because the bright bulb will radiate the heat it receives from the sun more freely.

Table B shows the Colombo method of recording the results of the black bulb thermometrical readings.

3. **Terrestrial Radiation.**—This is measured by a sensitive spirit minimum thermometer placed on a pad of non-conducting material (a blanket) resting on the ground, so that the bulb part is just prevented from touching the surface.

The Colombo readings are to be found in Table C.

Terrestrial radiation must not be considered by itself, but together with the presence or absence of clouds in the sky which prevent its action, and reflect the heat back to the earth when present. The condition of the sky in Colombo is given farther on in this chapter.

4. **Earth Temperatures.**—These are taken by Symon's earth thermometer, which is usually placed 1 foot below the surface. But a better plan is to have four thermometers, placed respectively 6 inches, 1 foot, 2 feet, and 4 feet in the ground.

The mean temperature of the earth increases as the depth, but the rate varies very much with geological conditions. Approximately it is placed at 1° C. for every 28 metres, or 1° F. for every yard.

This has proved of the greatest importance in the Temperate Zone, for in mines in Cornwall, Belgium, Italy, and elsewhere, agchylostomiasis, which is considered to be a tropical disease, is found, because the heat of some of these mines is quite tropical. This underground temperature must be carefully borne in mind when the question of ventilation of underground sewers in the tropics is considered, otherwise results the reverse from pleasant may ensue.

With regard to tropical earth temperatures, Lewis and Cunningham in Calcutta found that they varied with the season. In hot weather the thermometer stood highest in the air, next highest in the upper strata of the soil, and lowest in the lower strata. In cold weather this was reversed; in rain the relations were not constant.

Periodic Variations.

The temperature of a locality shows daily and annual periodic variations. The diurnal variation of temperature is due to the sun's rays falling upon dry earth and heating it; therefore this variation disappears at sea or during an Arctic winter.

Fig. 2 shows the curve of diurnal variation in Colombo, Ceylon; and on studying this, it will be observed that the maximum is reached between 1 and 2 p.m.—*i.e.*, about one and a half hours after the sun has reached its zenith.

The mean daily range of temperature is of great importance, because a considerable difference between day and night makes a climate dangerous if proper precautions are not taken.

Fig. 3 demonstrates the mean daily range of temperature in Colombo, from which it will be noticed that nowhere is the range very great, though it is most marked in December, January, and February, and least in June, July, and August, which is explicable by the proportion of cloud being greater in the latter than in the former months, as is shown in the following table:

Average Proportion of Clouded Sky in Each Month in Colombo, deduced from the Registers of the past 36-37 Years.

January	4·5	July	6·6
February	3·5	August	6·5
March	3·9	September	6·8
April	5·5	October	6·7
May	6·7	November	6·3
June	7·3	December	5·4

Where 1 denotes a perfectly clear sky, and 10, one entirely overcast.

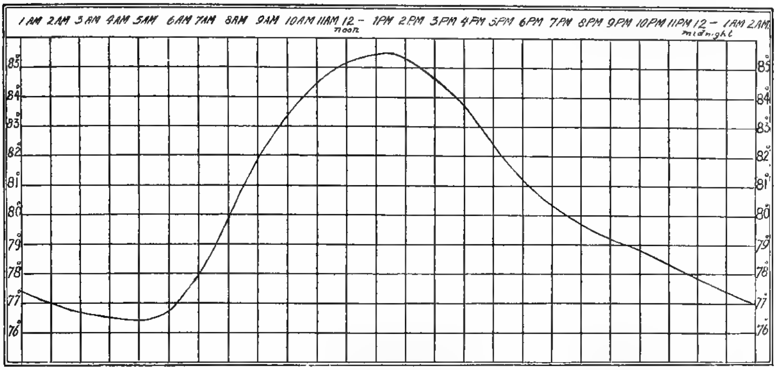

Fig. 2.—Diurnal Temperature-Curve at Colombo.
(Kindly given by the Surveyor-General of Ceylon.)

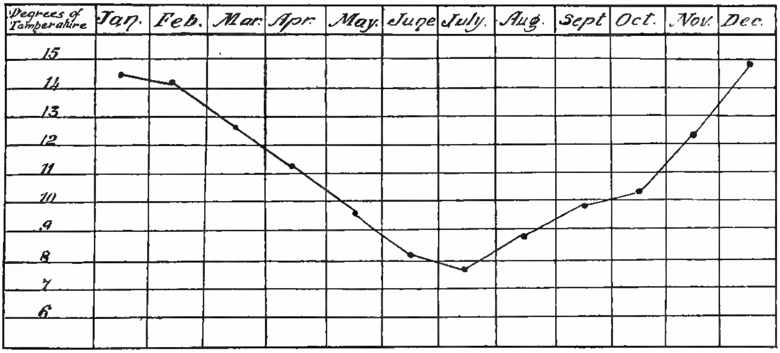

Fig. 3.—Mean Daily Range of Temperature in Colombo.

The Colombo curve may with advantage be compared with that of Jacobabad in Sind (Fig. 4), when the daily range will be seen to be much more considerable.

The annual curve depends largely upon the inclination of the world's axis as it passes round the sun in its yearly orbit. At the spring equinox, about March 21, the earth is so situated that the sun shines vertically upon the Equator at noon, after which its axis alters in position, so that the Northern Hemisphere is inclined more d more towards the sun, until the summer solstice—about June 22 -is reached, when the sun at noon is vertical over the Tropic Cancer, 23½ degrees north latitude, after which the inclination of e north towards the sun is lessened until about September 24. t the autumn equinox the sun is again vertical on the Equator, ter which the Northern Hemisphere inclines away from the sun, til the maximum declination is reached at the winter solstice, out December 22, when the sun is vertical over the Tropic of Capri- rn, 23½ degrees south latitude, after which it diminishes, until, on arch 21, the sun is again vertical over the Equator.

Hence, in the regions between the two tropics, the sun is vertical the sky at noon twice a year, at which time there is, or ought be, a wet season, and in the intervals a dry, hot season.

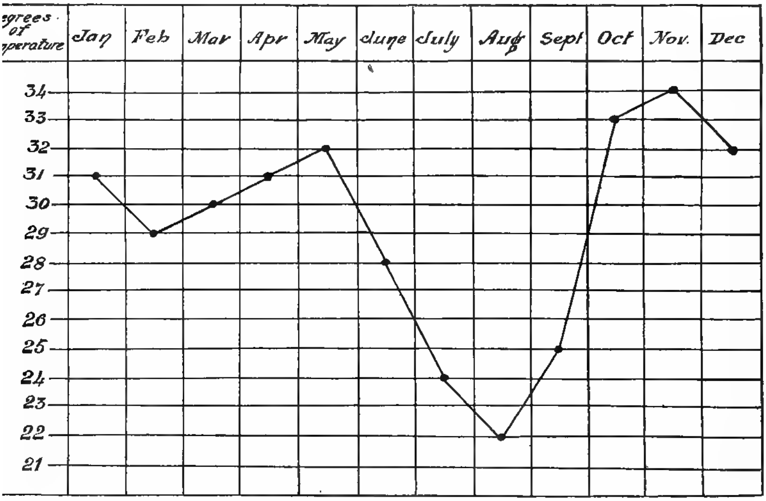

FIG. 4.—MEAN DAILY RANGE OF TEMPERATURE IN JACOBABAD.

The monthly mean temperature of Colombo is depicted in Fig. 5, hich shows that, though the extent of the range is small, still, riations do occur. Thus it is seen that in Colombo, with little oud, the temperature rises towards the March equinox; whereas in ptember, with much cloud, it is actually falling.

It will further be seen from the following table that March is dry, d that September 24 is approaching the heavy October rains:

MEAN RAINFALL IN COLOMBO FOR THE PAST 36 YEARS.

nuary	3·56	July	4·51
ebruary	2·10	August	3·59
arch	4·70	September	5·19
pril	10·90	October	14·67
ay	12·08	November	12·18
ne	8·17	December	5·87

It is the coincidence of the vertical position of the sun over Colombo, together with the rain at the same time, which makes the irregularity of the curve at the end of the year.

Compare the Colombo curve with that of Jacobabad (Fig. 6), where June, July, and August are the cloudy season, when the small annual rainfall takes place.

Altitude.

Another interesting feature of tropical temperature is its variation with altitude. Herschel pointed out many years ago that for every 300 feet of increase in altitude there is a decrease of 1° F. in temperature, and for every 180 metres a decrease of 1° C.—facts which, however, are only partially correct, for the temperature at a given altitude depends upon several factors :—

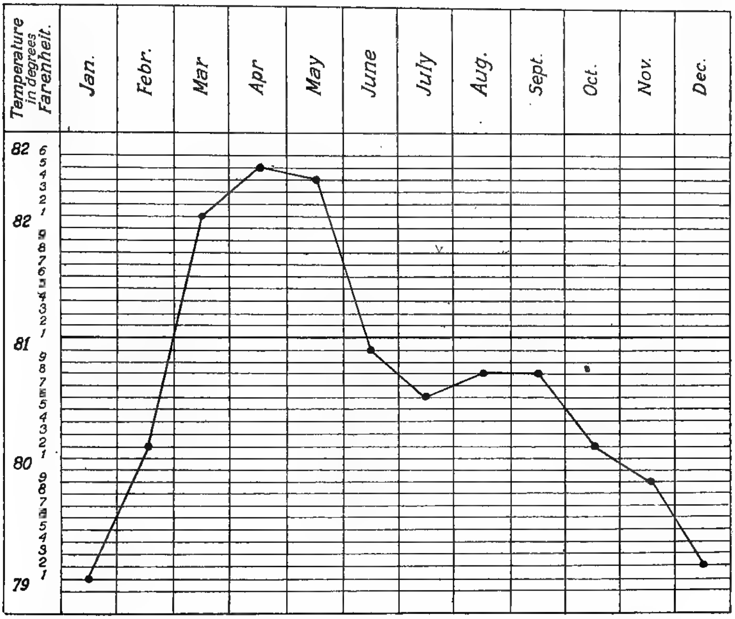

FIG. 5.—MONTHLY MEAN TEMPERATURE OF COLOMBO.

1. Expansion of the air.
2. Humidity of the air.
3. Clearness of the atmosphere.
4. Amount of earth.
5. Winds.

Perhaps of all these the most important is the expansion of air ; for it is well known that, when heated, it expands ; *i.e.*, the energy represented by heat is converted into motion, and hence the temperature falls. This will in part be counteracted by the heat produced by the condensation of aqueous vapour, even at high altitudes, as will be explained later, and upon this condensation and cloud-formation will depend how much of the heat, radiating from the earth into the air, is retained. The lessened amount of earth in high altitudes is also a factor, as there is less earth to retain heat, and hence less heat is given off into the air. It is obvious that movements of the air — the winds — must have a great effect, depending upon their origin from warm or cold sources. Hence, though in general the rule mentioned above as to a relationship between temperature and altitude holds good, it is only approximate, as the connection between the two is complex, not simple.

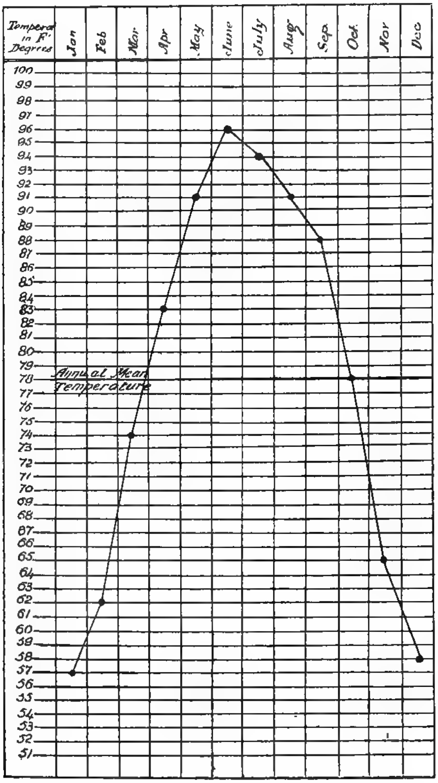

FIG. 6.—MONTHLY MEAN TEMPERATURE OF JACOBABAD.

In the tropics, therefore, the low country possesses the true tropical climate, while the climatological conditions of the hills are

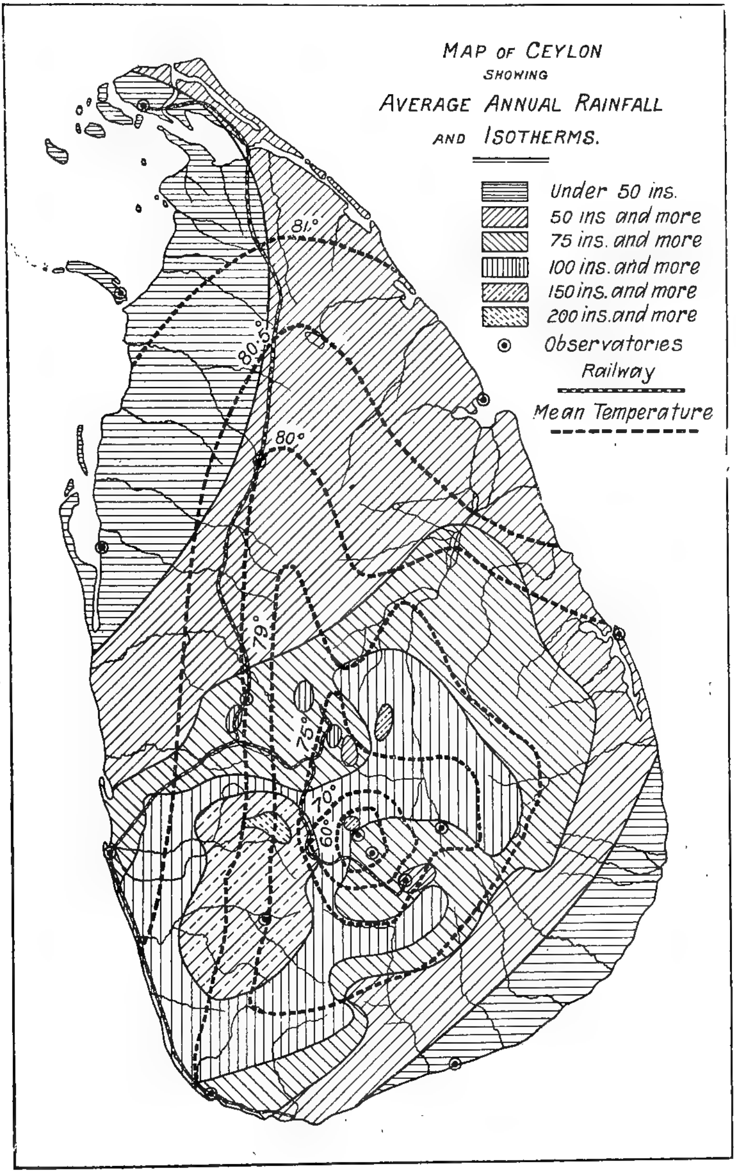

FIG. 7.—MAP OF CEYLON.
(Modified from a map given by the Surveyor-General of Ceylon.)

quite different. This phenomenon is well demonstrated in Ceylon, which has a low and a hill country, as depicted in Fig. 7.

For this purpose, compare the following tables of the temperature of Kandy, in which the height of the meteorological observatory is 1,654 feet, and of Newera Eliya, which is 6,240 feet, with that of Colombo, which is only 40 feet high.

AVERAGE MONTHLY MEAN TEMPERATURE OF STATIONS IN CEYLON.

	Colombo (Years 36-37).	Kandy (Years 35-37).	Newera Eliya (Years 35-37).
January	79·1	73·3	56·6
February	80·2	75·1	57·6
March	82·1	77·4	60·8
April	82·5	77·4	60·1
May	82·4	78·5	60·8
June	81·0	75·5	58·1
July	80·6	74·8	57·3
August	80·8	74·9	57·7
September	80·8	74·9	58·0
October	80·2	75·1	58·2
November	79·9	75·2	57·8
December	79·2	73·4	57·2
Average for year	80·7	75·5	58·4

In fact, as Herschel remarked, it is possible in the tropics, if you ascend high enough, to go through every degree of temperature, just as if you proceeded from the Equator to the Poles. This is a factor of importance in a tropical country, enabling people to get into cool weather by going into the hills when the plains are very warm.

But the practitioner must remember that, however beneficial this change may be, a sick person must approach it gradually. For example, if a person just recovering from a severe illness takes a train at 10 p.m. at night in Colombo, in March, with a mean temperature of 82·1° F., and arrives at about 8 a.m. the next morning in Newera Eliya, with a mean temperature of 60·8° F. and a mean minimal temperature of 45° F., the sudden change of temperature is apt to be very dangerous.

PRESSURE.

Atmospheric pressure, which comes next in importance to temperature in meteorology, is measured by means of the barometer; but the reading has to be corrected for many errors—*e.g.*, index error, capacity, capillarity, temperature, and altitude.

The result of this investigation shows that, generally speaking, at sea-level there is high pressure at about 30 degrees north or south of the Equator, and that from this the pressure decreases towards the Equator.

The reason why the pressure is low at the Equator is partially due to the heating of the air by the sun's rays, but more especially to the considerable addition of aqueous vapour to the air in these regions, with the result that it ascends with considerable force, and goes on ascending to very high altitudes, owing to repeated warming from the condensation of aqueous vapour and the liberation of latent heat.

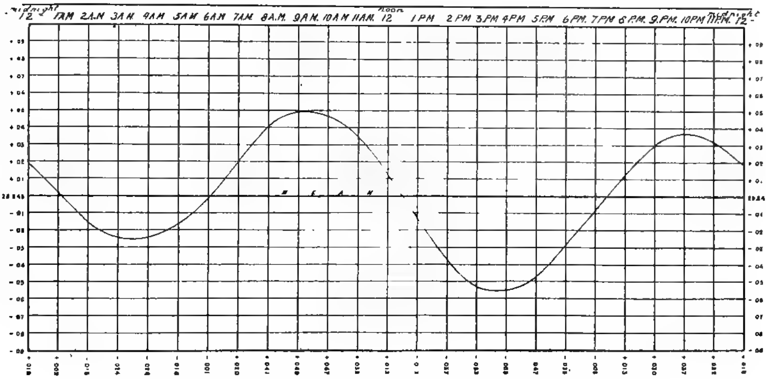

FIG. 8.—DIURNAL BAROGRAPHIC CURVE AT COLOMBO.

Though the pressure at 30 degrees is higher than that at the Equator at sea-level, it is considerably less than at higher altitudes. Consequently air passing upwards from sea-level at the Equator into higher strata will then flow either north or south towards 30 degrees; but as it flows it is compressed as the latitude increases, and hence the current of air flowing polewards becomes narrower and narrower, and finally, owing to this, is forced down by the increasing pressure, until it reaches sea-level at 30 degrees north or south, causing the high pressure about this latitude. This compression is helped by the cooling of the air as it proceeds polewards, and by the centrifugal force of the earth's rotation.

Apart from this general distribution, there are diurnal and annual variations in the pressure. The diurnal variation of pressure is best marked in the tropics, diminishing as the Poles are approached —*e.g.*, at Calcutta it is 0·12 inch, whereas at Greenwich it is only

TABLE D.

MONTHLY MEANS AND EXTREMES OF PRESSURE IN COLOMBO.

Month.	Mean.	9.30 a.m.	3.30 p.m.	Range.	Highest Reading.	Date.	Lowest Reading.	Date.	Absolute Range
	29+	29+	29+	—	29+	—	29+	—	—
January	0·911	0·974	0·848	0·126	1·047	1st	0·784	25th	0·263
February	0·892	0·957	0·827	0·130	1·019	27th	0·752	19th	0·267
March	0·874	0·940	0·809	0·131	1·042	4th	0·717	21st	0·325
April	0·852	0·903	0·802	0·101	0·975	27th	0·737	1st	0·238
May	0·812	0·861	0·763	0·098	0·935	4th	0·712	10th	0·223
June	0·851	0·898	0·804	0·094	0·929	10th	0·763	3rd & 28th	0·166
July	0·846	0·889	0·804	0·085	0·926	18th	0·764	16th	0·162
August	0·839	0·880	0·798	0·082	0·961	6th	0·739	17th	0·222
September	0·850	0·901	0·799	0·102	0·959	16th	0·749	10th	0·210
October	0·846	0·899	0·793	0·106	0·954	23rd	0·728	11th	0·226
November	0·894	0·954	0·834	0·120	1·023	26th	0·776	11th & 12th	0·247
December	0·867	0·927	0·806	0·121	0·980	25th	0·746	9th	0·234
Year	0·861	0·915	0·807	0·108	1·047	January 1st	0·712	May 10th	0·335
Means of extremes . .	—	—	—	—	0·979	—	0·747	—	0·232

The monthly variations of pressure for Colombo are shown in Table D.

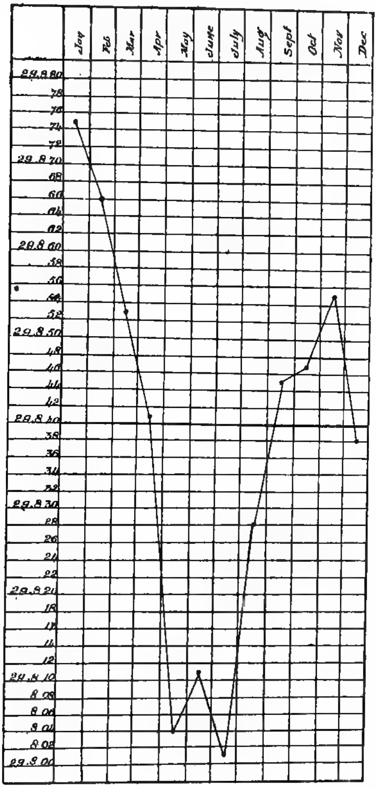

FIG. 9.—AVERAGE MONTHLY MEAN PRESSURE AT COLOMBO.

The cause of these seasonal variations in the pressure is the heating or cooling of the land, which, in the case of Colombo, is associated with the monsoons. Thus, the low pressures occur in the season of the south-west monsoon, May, June, and July (Fig. 9), when air is travelling from high pressure at the Equator to low pressure in the warm plains of Asia; and the high pressures are associated with the north-east monsoon, when air is travelling from the cold plains of Asia, where it is at considerable pressure, towards the Equator, where the pressure is less.

It is obvious that the air will move from regions of high pressure to those of low pressure. These movements of the atmosphere are called 'the winds,' which are the next topic upon which a few remarks must be made.

MOTION OF THE ATMOSPHERE (WINDS).

The movements of the atmosphere called 'winds' may be classified into:—

Permanent Winds.
Periodical Winds.
Variable Winds.
Local Winds.

Permanent Winds.

The hot air of the tropics expands, and rises to great heights, as already explained. By this expansion, air is drawn from the north and the south towards the Equator—in fact, the primary cause of the motions of the atmosphere is the unequal distribution of heat on the world's surface, for if heat were uniformly distributed there would be no motion of the air.

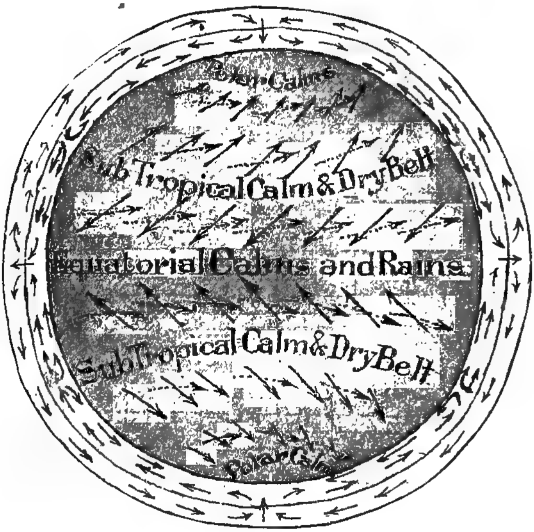
Polar Calms
Sub Tropical Calm & Dry Belt
Equatorial Calms and Rains
Sub Tropical Calm & Dry Belt
Polar Calms

FIG. 10.—DIAGRAM OF THE CIRCULATION OF THE ATMOSPHERE. (After Ferrell.)

The general circulation of the atmosphere is shown in Fig. 10, which demonstrates Ferrel's latest ideas. It will be noticed that vertical section of the atmosphere in which the arrows indicate the movements. The equatorial area is marked in the centre.

If this figure be carefully examined, it will be seen from the section of the atmosphere on the sides of the figure that the heated air rises over the Equator to high altitudes, and flows to the poles but at lesser altitudes it descends in the region of subtropical calms and either passes polewards or to the Equator. Within the area from 0 to 30 degrees there are winds called 'the trades,' which blow from 30 degrees towards the Equator, and which, on reference to Fig. 11, can be noted as north-east trades and south-east trades and it will also be observed that the only portion of the ocean free from them is the North Indian Ocean, where the south-west monsoons occur. The north-east monsoon is really a trade-wind.

Further, it will be noted that as the air moves in opposite directions along the surface in the region of latitude 35 degrees, there is an absence of prevailing winds. These belts of calms are called 'the subtropical belts,' or the calms of Cancer and Capricorn. Again, at the Equator there are calms for the same reason, and these are often called 'the doldrums.'

The trade-winds are only to be seen typically in oceanic regions, where the temperature is equable, and there are no local conditions to cause them to deviate from their course. But they, together with their intermediate zones of calms, shift their positions according to the temperature, having, therefore, different areas in such months as March and September. On an average the north-east trades extend from 7 degrees to 29 degrees north in the Atlantic, and the south-east to 20 degrees south. During the summer they advance a few degrees north, and in the winter recede to the south. In spring the centre of the doldrums is only 1 to 2 degrees north of the Equator, while in summer it is about 9 or 10 degrees north latitude, and, as will be explained later, the tropical rains of certain regions depend upon this movement. Their easterly direction is due to the rotation of the world.

Periodical Winds.

When large tracts of land are heated by the sun at one time of the year and not at another time, the movements of the air are bound to be influenced by this alternate heating and cooling, and the result is that periodical winds are produced.

The most important of these to the student of the tropics are the monsoons. The word is derived from the Arabic word *mansin*, meaning 'a season,' being probably simply a corruption of this term.

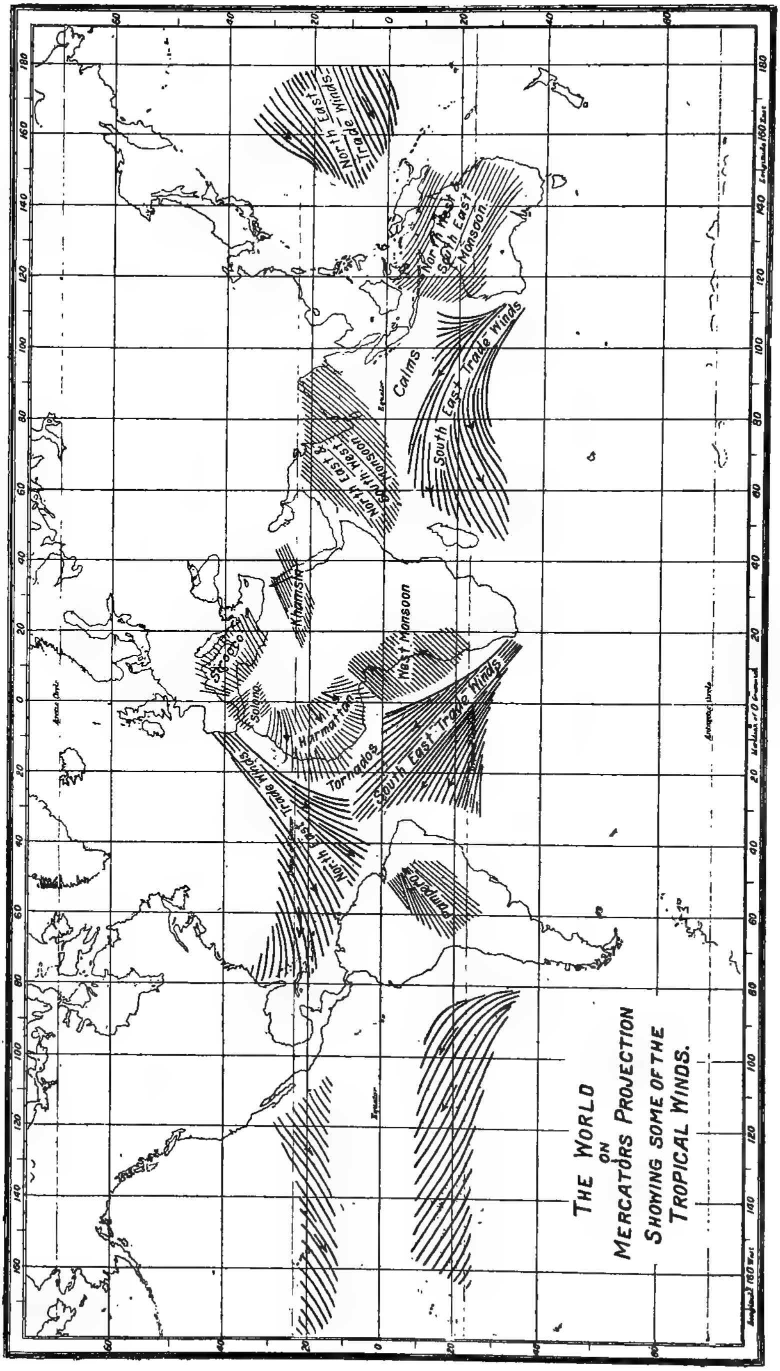

FIG. 11.—TROPICAL WINDS.

1. **North-East and South-West Monsoons.**—These are typically met with in the Indian Ocean and its coasts.

Dove's explanation of these monsoons is generally accepted—viz., that, owing to heating of the great plains of Asia, where the air ascends in the months of May, June, July, and August, the south-east trade-wind, which is blowing south of the Equator, is drawn northwards, at the same time being deflected to the west, thus forming the south-west monsoon. Conversely, when the plains cool in November, December, January, February, and March, there is a breeze from the north-east towards the Equator, which, though called the north-east monsoon, is really a trade-wind.

The interval between the two monsoons is characterized by changeabl winds, which blow alternately in opposite directions—north-east and south west.

The south-west monsoon is laden with moisture, and on it Southern Indi largely depends for rain, and a failure will mean a famine, because a larg portion of the population is agricultural, for the natives depend for food upo their own cultivation; and so densely are they placed that a failure to produc their own crops results in a most severe famine, which can only be coped wit by the most energetic action of the Government.

2. **North-West and South-East Monsoons.**—These are to be found in th Southern Hemisphere, and are depicted in Fig. 11 in the region of Australia.

3. **West Monsoon.**—Dove described as the west monsoon of the line wind which blows in a south-westerly direction along the coast of Afric from Cape Verde down to Walfisch Bay. These winds, however, are variable and in the Gulf of Guinea are interrupted very often by calms.

Some people describe the winds along the eastern and western coasts o South America as monsoons, but they hardly come under this term.

Variable Winds.

In the tropics these winds are found in the regions of calms interposed between the trades in the Atlantic and Pacific Oceans.

The region of equatorial calms does not extend across the oceans but is broadest on the eastern side, and is very thin in mid-ocea or on the western side, the two trades appearing to meet.

Local Winds.

Local winds are of great importance in the tropics, constitutin the so-called land wind, sea-breeze, mountain wind, etc., and severa others to be referred to later, to which special local names have bee given.

The wind about which a great deal is spoken in every tropica country is 'the land wind.' During the day the land become heated by the sun, and causes the air to rise, thus lessening th pressure, and drawing the air from the sea, causing a sea-breeze which is, of course, very humid. During the night, however, b terrestrial radiation, the land becomes cooler than the sea, and th air travels from the land to the sea, and constitutes the land wind This wind, as a rule, is dry, and has a very deleterious effect o men and animals by extracting moisture and abruptly cooling the body, and thereby lowering the resisting-power to disease. Hence the complaints made by old residents about the land breezes. On the other hand, new-comers delight in them, because they are cool.

This land wind is more marked at certain seasons of the year than at others, being particularly felt in Colombo in those months when there is less cloud, because the terrestrial radiation is then more marked. There is, however, nothing like a definite season for a pronounced land wind, for it can take place at any time, only depending upon terrestrial radiation.

A few remarks may be useful with regard to some local winds.

The Sirocco (Italian, *scirocco*).—The sirocco is a south-east wind with a high temperature, which, coming from the high land of North Africa, descends to the Mediterranean, and may reach Malta and some parts of Italy. It is considered to be very enervating.

The Solano.—The solano is a south-easterly wind, blowing from the Sahara into Spain.

The Harmattan.—The harmattan is a hot easterly wind, coming from the Sahara Desert, and carrying dust far out into the Atlantic.

In the months of November to March this wind meets with the north-east trade in its most southerly position, with the result that it is deflected southwards down the west coast of Africa. It is a very dry wind, and therefore extracts moisture from everything it comes across. Hence human beings feel their skin dry and hard, and may suffer from bleeding from the nose and lips, while furniture creaks and groans in a most supernatural manner.

The Khamsin.—The khamsin, or khamseen, is the dust-laden wind which blows from the Sahara into Egypt at intervals during fifty days about Eastertime, and is very disagreeable.

Pamperos.—These are the south-westerly winds of Brazil. Europeans have altered the significance of the name to squally cyclonic winds in the same vicinity.

Storms.

Besides ordinary winds, cyclonic disturbances called storms occur. Cyclonic storms receive different names in various parts of the world, being called cyclones in India, Ceylon, and Mauritius, hurricanes in the West Indies, typhoons in the China Seas. Mild cyclonic storms met with on the west coast of Africa and elsewhere are called tornadoes.

The air of the tropics is highly charged with electricity, and silent electrical discharges are frequent, causing an increase in the nitric acid in the air, which ruins cover-glasses and lenses. This electrical condition may give rise to thunder-storms, which in most parts of the tropics are very intense, and deaths from lightning not infrequent. The thunder-storms of the tropics are mostly heat-storms, due to great differences in temperature in adjacent masses of air. Hail may fall during a thunder-storm.

HUMIDITY.

Man can bear very high temperatures easily, provided the air is dry, but not if there is much moisture or humidity in it. The humidity of the atmosphere is, in fact, of the utmost importance abundance into the air over tropical seas ; but aqueous vapour, being lighter than air in the ratio of 0·623 to 1·0, helps it to rise to cold altitudes, where the vapour condenses into small droplets of water, forming mist or cloud. If the droplets become too heavy to remain in the atmosphere, they fall as rain. Condensation sets free latent heat, which warms the surrounding air, and makes it rise to higher altitudes, where condensation and liberation of heat may again take place, and this may be repeated until the cirrus clouds are formed at a height of about five or six miles.

The humidity of the atmosphere, therefore, presents three problems :—

1. How much water is being evaporated ?—Atmometry.
2. How much aqueous vapour is there in the air ?—Hygrometry.
3. How much water is being condensed out of the atmosphere ?—Hyetometry.

Evaporation takes place most quickly in hot dry air, and causes a considerable amount of heat to be rendered latent.

This fact can be made use of in hot climates, where it is a common practice to wrap flannel or felt round a bottle of water, and after damping the flannel, to hang the bottle in the breeze, so that the contents may become cooled by the evaporation of the water from the flannel. The same principle applies to the porous stone or earthenware basins which are commonly used in Ceylon, Uganda, Egypt, and other parts of the tropics to filter and cool water. Hence, also, the value of collections of water in keeping the temperature of places equable.

The amount of aqueous vapour in the atmosphere is generally spoken of as the humidity. Two kinds of humidity are recognized : absolute humidity, which is the weight of aqueous vapour actually present in a definite volume of air at a given temperature ; and relative humidity, which is the ratio of the weight of water actually present in a known volume of air to the weight of water which is required to saturate the same volume of air at the given temperature, and is generally expressed as a percentage.

We have already stated that the humidity of the air is of the greatest importance in considering the effects of a tropical climate on man. The most trying climate would be one with a high air temperature and a high relative humidity, for it is obvious that when the air is full of aqueous vapour, evaporation from the surface of the human body must be considerably diminished ; and as this is one of the methods of regulating the bodily temperature, it is apt to rise and cause great discomfort, as will be described later in the chapter on the effects of climate on man.

A warm place with a high humidity is less bearable than a much hotter but drier place. A fairly high relative humidity can, however, be borne if there is a breeze, without which a much lower humidity is most unbearable. In fact, Giles points out that Abusher, in the Persian Gulf, in August, with a mean maximum temperature of 96·5° F. (35·7° C.), and a relative humidity of 65 per cent., with no rainfall during the month, and little or no breeze, constitutes one of the most unbearable climates in the world, though neither the temperature nor the humidity by themselves are high.

The general conditions in Abusher can be judged from the following table, taken from Giles's 'Climate and Health in Hot Countries':—

Month.	Mean Maximum Temperature.	Mean Minimum Temperature.	Relative Humidity.	Rainfall in Inches.
January	65·2	52·0	79	3·39
February	66·0	52·5	80	2·51
March	72·6	58·2	72	0·87
April	84·6	66·1	61	0·58
May	89·8	75·3	60	0·02
June	92·2	80·3	61	—
July	95·5	84·0	65	—
August	96·5	83·6	64	—
September	94·2	78·8	65	—
October	87·9	70·7	65	—
November	78·0	62·1	74	2·16
December	69·7	55·5	73	3·98

Colombo, in Ceylon, which lies at sea-level, has a bearable climate, with the following conditions, which with advantage may be compared with those of Abusher:—

Month.	Mean Maximum Temperature.	Mean Minimum Temperature.	Relative Humidity.	Rainfall in Inches.	Average Diurnal Velocity of the Wind in Miles.
January	86·8	72·2	77	3·56	146·7
February	87·4	73·0	76	2·10	157·7
March	89·3	76·6	76	4·70	131·7
April	87·8	76·7	77	10·90	122·1
May	87·2	77·6	81	12·08	213·5
June	86·0	77·9	81	8·17	249·9
July	86·4	78·6	81	4·51	223·1
August	87·5	78·7	82	3·59	218·9
September	86·1	76·2	79	5·19	288·5
October	85·5	75·1	81	14·67	176·6
November	87·4	75·1	81	12·18	147·5
December	88·2	73·2	78	5·87	208·3

Compare this, again, with the figures for Newera Eliya, the sanatorium of Ceylon, situated some 6,240 feet above sea-level:—

January ..	67·7	45·3	82	5·38	81
February ..	70·4	44·4	77	2·15	86
March	72·2	45·0	75	2·97	78
April	69·4	51·4	81	6·10	75
May	68·4	54·6	84	7·69	92
June	67·2	53·5	91	13·64	153
July	66·0	51·5	89	11·76	147
August	67·2	54·5	89	8·14	125
September ..	67·1	53·4	89	8·26	112
October.. ..	68·0	51·7	88	10·61	98
November ..	67·3	54·9	87	8·80	75
December ..	66·9	48·1	86	8·53	77

It will be observed that, notwithstanding its high relative humidity, Newera Eliya has a low temperature, due to its altitude, and a very fair rainfall, and consequently makes a most admirable hill-station for Ceylon.

Note particularly the difference between Colombo and Newera Eliya for February, March, and April, which are the hottest months for the former town, whereas the latter forms an excellent climate for European ladies and children at that season.

The monsoon bursting about May 24 cools Colombo considerably, and the need for residence in Newera Eliya is ended for the year; this is a fortunate circumstance, for the rainfall there in June is considerable.

Ceylon, however, is well provided, for the ranges of hills stop the rain, and at Bandarawella and Diyatalawa, a few miles from Newera Eliya, it is fine at this time of the year, and a second sanatorium is available.

The climate of Diyatalawa, once a camp for Boer prisoners, and now a naval and military sanatorium, is as follows (altitude, 4,500 feet):—

Month.	Mean Maximum Temperature.	Mean Minimum Temperature.	Relative Humidity.	Rainfall in Inches.	Average Diurnal Velocity of the Wind.
January	69·8	57·9	82	8·00	145·5
February	74·8	53·3	70	2·22	157·6
March	79·7	53·9	67	2·07	131·1
April..	79·6	57·9	77	6·92	120·9
May	77·8	62·4	74	5·36	213·1
June..	75·2	62·3	70	2·06	249·4
July	76·1	61·7	67	1·24	223·6
August	79·0	61·4	66	2·46	218·1
September	76·0	61·5	73	3·87	290·2
October	74·7	60·7	78	11·47	177·3
November	73·0	58·7	85	10·20	147·8
December	70·3	58·3	83	6·63	207·0

Another comparison, taken from Giles, may with advantage be considered—viz., Old Calabar, on the west coast of Africa :—

Month.	Mean Maximum Temperature.	Mean Minimum Temperature.	Relative Humidity.	Rainfall in Inches.	Number of Rainy Days.
January	90	68	78·8	2·68	1
February	94	72	78·1	6·69	5
March	94	71	81·6	7·70	8
April	93	71	75·8	11·01	10
May	94	75	77·6	10·95	19
June	92	71	84·4	32·59	22
July	90	70	85·8	13·61	25
August	86	70	88·2	6·39	15
September	92	70	85·7	11·84	25
October	91	70	82·6	9·38	17
November	91	71	83·6	11·34	12
December	89	70	83·6	1·32	1

When the mean maximal temperature and the relative humidity are compared together, it is not astonishing that certain regions of West Africa are very trying to the human constitution.

As an example of a place with a low relative humidity and a high maximum temperature and very little rain, the following data concerning Omdurman, taken from Giles, may be quoted :—

Month.	Mean Maximum Temperature.	Mean Minimum Temperature.	Relative Humidity.	Rainfall in Inches.
January	88·5	62·6	24	—
February	94·5	70·2	28	—
March	99·7	—	19	—
April	103·7	72·5	14	—
May	112·0	79·0	20	—
June	106·2	77·4	46	0·63
July	103·9	79·3	48	0·50
August	99·0	77·7	58	0·13
September	104·5	81·0	40	—
October	103·2	79·5	30	0·32
November	96·7	72·4	24	—
December	91·2	65·5	28	—

When the aqueous vapour in the atmosphere condenses, the result may be dew, fog, mist, cloud, rain, hail, or snow, of which the two last are rare in the tropics.

Clouds in the sky prevent to a great extent the heating of the earth during the day, and at the same time they prevent radiation of heat from the earth during the night, and even reflect this back to it. Hence cloudy nights may be very hot in the tropics.

As already stated, the whole system of trades and calms moves from the Equator northwards about 5 to 8 degrees, or southwards 3 to 4 degrees of latitude. This movement is dependent upon the inclination of the axis of the earth towards the sun, though not coincident with it. They are, therefore, farthest towards the north in July, and towards the south in January.

A locality may lie—

(1) Within the rain-belt in both of its extreme positions.

(2) Just within the equatorial boundary of the rain-belt in its farthest position polewards.

(3) Just within the polar boundary of the rain-belt in its farthest position polewards.

(4) Between (2) and (3).

(5) Beyond (3).

1. Places within the Two Positions of the Rain-Belt.

These are equatorial, and are always more or less subject to rain and cloud, because the heated air is full of aqueous vapour brought by the trade-wind from the sea. When this very humid air rises to high altitudes, it becomes cooled, and therefore the moisture condenses as cloud and rain.

Again, these regions are subject to alternate seasons of wind and calm—*e.g.*, in January they will be subject to the north-east trades, followed by a period of calm; and in July to south-east trades, succeeded by a period of calm. These places will therefore have two short wet seasons and two short dry seasons.

Such a place is Ceylon, and its conditions of rain and cloud can be easily understood by referring to the tables of rainfall and cloud distribution already given for Colombo.

Other similar places are South India and Java in Asia, Columbia in South America, and parts of the Nile Basin and the Gold Coast in Africa.

2. Places just within the Equatorial Boundary of the Rain-Belt in its farthest Position Polewards.

The inclination of the North Pole towards the sun begins on March 21, and ceases on September 24. The shifting of the rain-belt northwards begins some time after the first date, and ends some time after the last date, for it lags behind. A locality situated in this position will, therefore, be in the belt for six months. Therefore in such places there will be six months' rain and six months' drought. Those places are Bengal, the Nile Basin, Northern Australia, and Central America.

3. Places just within the Polar Boundary of the Rain-Belt in its farthest Position Polewards.

These places have a short wet season lasting only three months, and a long dry season lasting nine months. Such places are the Punjaub, Upper Burma, Mexico, Central Australia. In the Punjaub, for example, there are three seasons—(1) Hot season: April to June. (2) Wet season: June to September. (3) Cold season: September to April.

4. Places between (2) and (3).

These places will vary from the maximum of six months rain to the minimum of three months.

5. Places situate just outside the Polar Boundaries of the Rain-Belt.

These places lie from about 20 to 35 degrees north or south latitude, and are among the driest in the world, except in India, where the south-west monsoon brings a little rain into the dry regions of the Punjaub and Sind.

The worst places are the dry zones of California and other parts of North America, the Sahara and Nubian Deserts, parts of Arabia and Persia, Argentina, Eastern Patagonia, South-West Africa, and the interior of Australia. The only rain these regions are likely to get will come from the extension equatorially of the polar winds.

If these conditions of rainfall in the tropics are clearly understood, they form the key to tropical climatology, for it will be seen that the wettest, as well as the driest, places in the world are found in them.

It must, however, be remembered that ranges of mountains are most important in determining the rainfall of a locality by stopping the clouds, and leading to further condensation of the moisture as rain. The influence of hills is well shown in Fig. 7 of the Ceylon rainfall, taken from the Surveyor-General's report.

The driest places in the world are in Africa, in the neighbourhood of the Sahara; but India shows the extremes of dry and wet climates best. Jacobabad, according to Blandford, has an average annual rainfall of 4½ inches, which in some years is less than 1 inch; whereas Cherrapunji, in the Khasi Hills in Assam, has an annual fall of from 500 to 600 inches per annum.

In Ceylon the wettest place recorded is Padupola, which, with an elevation of 1,606 feet, has a rainfall of 230·50 inches as an average of thirty-five years' observations.

But it is not merely the average rainfall which is so excessive in the tropics, but the rate at which it comes down; *e.g.*, according to Blandford, on June 14, 1876, no less than 40·8 inches of rain fell at Cherrapunji in twenty-four hours. The excessive violence of tropical rain can be explained by the fact that at 20° F. air takes up 1·3 grains of water per cubic foot; at 60° F., 5·77 grains; at 85° F., 12·78 grains. Further, when air saturated at 85° F. is cooled to 60° F., every cubic foot will yield 7 grains of water (Hill).

Ward has recently subdivided these regions by utilizing the winds and the rainfall into—

1. The equatorial belt.
2. The trade-wind belts.
3. The monsoon belts.
4. The mountain climates.

The equatorial belt extends about 10 degrees on either side of the Equator, and is characterized by its temperature, showing two maxima corresponding to the two zeniths of the sun, and two minima corresponding to the two solstices, and should have two wet and two dry seasons.

In this belt lie such places as Singapore and Batavia, which are fairly healthy, and the west and east coasts of Africa, which are very trying.

The trade-wind and monsoon belts have already been considered, as have the mountain climates.

Psycho-Physical Aspects of Climate.

Tyler has attempted to correlate personal sensations with meteorological data under the term 'Psycho-Physical Aspects of Climate,' and says that his 'hyther' degrees—by which he means the degree of discomfort caused by high air temperatures associated with high relative humidity—are the best methods of comparing climates. This naturally brings us to the next subject to be considered, namely, the effect of warm climates on man.

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CHAPTER III

THE EFFECTS OF TROPICAL CLIMATES ON MAN

Production and regulation of heat in man—Normal temperature—Effects of temperature and humidity—Effect on digestion—Effect on respiration—Effect on circulation and the blood—Effect on bodily temperature—Effect on the nervous system—Effect on the urinary system—Effect on the generative organs—Effect on growth—Effect of light—Acclimatization—Prophylaxis.

THE climatic factors which most actively affect man in the tropics are the temperature and humidity of the air and the chemical rays from the sun, and to these the following remarks will be restricted.

Before beginning to describe what is known of these effects it is necessary to review briefly the physiological problems of the heat of the body, its production, and its maintenance. This may be thought to be superfluous, but it is intimately associated with a proper understanding of heat-stroke, and cannot altogether be omitted, though it will be dealt with as briefly as possible.

PRODUCTION AND REGULATION OF HEAT IN MAN.

Heat is produced by oxidation of proteid, carbohydrate, and fatty substances, mostly in the muscles, and to a less extent in the glands and other organs and tissues of the body, and depends, therefore, largely upon the intake, digestion, and assimilation of food, and can be increased by rich feeding. This effect of food is more marked if the air temperature is high; hence the danger of overfeeding and alcohol in the tropics, for unless the increased production of heat is compensated by increased loss, the body temperature may rise. On the other hand, too little food will produce poor development and diminished metabolism, which will result in the changes shown in the blood and urine in Bengalees, as will be noted later.

McCay has recently studied this subject carefully, comparing the diets of Bengalees with those of Anglo-Indians and Eurasians. The results of his work are shown in the table on p. 50.

Further, he points out that there is a great waste of nutriment, in that 25·42 per cent. of the nitrogen of the food appears in the fæces of the Bengalees, and only 15 per cent. in Europeans on a vegetable diet, a difference which he ascribes to the use of dhal, which he also considers to be the cause of the bowel disorders so commonly met with in Bengalees.

Food.	Bengalees I.	Bengalees II.	Anglo-Indians and Eurasians.
Proteids in grammes	67·11	43·61	86·56
Carbohydrates in grammes ..	548·73	200·31	376·53
Fats in grammes	71·55	33·92	54·75

Air temperatures have also an effect on metabolism, and hence on heat production, for it has been shown that in fasting animals there exists an external temperature at which a good bodily condition can be maintained by a minimal metabolism. Above and below this temperature, which is called 'the critical temperature,' metabolism is increased. In man the critical temperature is said to lie between 15° C. and 20° C.

According to Vierordt the heat of the body is lost in the following manner :—

	Per Cent.
Warming the urine and fæces	1·8
Warming the expired air	3·5
Evaporation from the lungs	7·2
Evaporation from the skin	14·5
Radiation and conduction from the skin	73·0
Total	100·0

The temperature of the body is therefore regulated by—

(1) Chemical heat regulation,
(2) Physical heat regulation,

which probably work hand in hand, and are indirectly under the control of the nervous system, which governs the activity of the muscles and other tissues, and also the vessels by the vasomotor nerves, and the sweat glands by the sweat nerves.

1. **Chemical Heat Regulation.**—By this is meant regulation of the bodily temperature by increased or diminished production of heat, which can be brought about by alterations in metabolism. Diminished heat production is, however, rare, being usually pathological, though it is possible that it occurs more frequently in the tropics than in the Temperate Zone, owing to the lessened disposition for muscular or mental work.

2. **Physical Heat Regulation.**—The body temperature is usually regulated by increasing or diminishing the loss caused by radiation, convection, and evaporation. According to Hill, a man weighing 70 kilogrammes loses 77·1 per cent. of his heat by radiation and convection, and 22·9 per cent. by evaporation. This regulation is

brought about by the dilatation of the cutaneous vessels bringing more blood to the skin and by the increased perspiration. The loss of heat caused by radiation and convection depends upon—

1. Temperature and conductivity of the skin.
2. Temperature and radiation from the skin.
3. Temperature of the air.
4. Rate of motion of the air.

Clothing may, however, affect the loss of heat from the skin, for, as a rule, it is composed of substances which are bad conductors of heat, and hence the loss may, according to Rubner, be diminished no less than 47 per cent. Wet clothing, on the other hand, is a good conductor, because of the water in its interstices, and hence the danger of chills while wearing damp clothes. This latter fact is well known to the old resident of the tropics, who has generally learnt its danger by personal experience.

Radiation takes place best when the air is still, dry, and cold, conduction when it is damp. Convection is only of importance when the air is in motion, in which case the loss of heat is proportionate to the square root of the velocity, and is more marked when atmospheric humidity is high.

With regard to evaporation, Rubner has shown that it is least at medium, greater at low, and still greater at high, temperatures, as is shown by the following table taken from his work of an observation on a man of 58 kilogrammes weight lightly clad :

Air Temperature.	Grammes of OH_2 lost per Hour.	Grammes of CO_2 lost per Hour.
2° C.	37	29·8
10° to 15° C.	28	25·1
15° to 20° C.	19	24·1
20° to 25° C.	23	25·0
25° to 30° C.	43	25·3
30° to 35° C.	84	23·7
35° to 40° C.	112	21·2

This evaporation is very markedly diminished by humidity, as is shown in the following table :

Temperature in Centigrade.	5 to 8 per Cent. Humidity.	81 to 89 per Cent. Humidity.
15·0°	36·3	9·0
20·4°	54·1	15·3
25·3°	75·5	23·9
28·9°	105·0	—

It is also diminished by a moderately strong wind, but is increased by the sun's rays and by work in a hot climate.

NORMAL TEMPERATURE.

The temperature of man, being the resultant between the heat produced and the heat lost, must vary considerably under many circumstances.

In investigating the temperature of the body, one ought to seek that which most nearly represents the temperature of the blood, for though the different organs of the body manufacture or lose heat in different proportions, the circulation of the blood tends to bring about a mean internal temperature for the whole body.

The possible methods of investigating the temperature of the body are by placing the thermometer—

1. In the axilla,
2. In the mouth,
3. In the rectum,

to which might be added placing the thermometer in the stream of issuing urine; but this method is only open to limited application, and there may be considerable loss from evaporation and radiation, and therefore, though it is an excellent method when used with care, will not be further considered.

If the thermometer is placed in *a dry, well-closed axilla*, and kept there long enough, the result will be not unlike that in the *mouth;* but if it is thought that any resemblance to the internal temperature of the body is to be obtained by placing a thermometer in a perspiring axilla for half to one minute, then the greatest mistakes as to the real temperature of the patient are possible. In our experience it has not been unusual in the tropics to find several degrees of difference between the axilla and the mouth.

As a rule, it may be stated that the axilla is not a good place in which to take thermometric observations which are meant to indicate the true temperature of the body.

With regard to the mouth temperature, there has been a great deal of discussion, but the most careful observations are those of Pembrey and Nicol, who have shown that the mouth temperature is apt to vary considerably, and that it is not a reliable indicator of the internal temperature of the body in cold weather or after exercise. Haldane, in his valuable experiments to be quoted presently, finds that it varies greatly with the individual.

In warm and moist air, however, the mouth temperature approaches the rectal temperature.

The reason why the mouth temperature is apt to be lower than the rectal, and the real temperature of the body, is apparently the cooling owing to the proximity of the skin, and possibly of the nasal cavity, and therefore in warm air this difference frequently does not exist. In India Crombie found, in fifteen carefully taken observations, that the mouth temperature was 0·22° below that of the rectum, whereas Pembrey found it as much as 4·5° F.—*i.e.*, 2·5° C.—below that of the rectum in cold weather in England.

It is possible, therefore, that it is a better site for thermometric observations in the tropics than in Europe.

Rectal temperatures under ordinary conditions give the highest readings, and are the truest indicators of the internal temperature of the body; but this is not a method open to clinical use, except in children and in states of coma.

The conclusion is that if care be taken that neither hot nor cold articles have been recently placed in the mouth, and particularly if the mouth has been kept closed for a short time, the temperature from the thermometer placed under the tongue is, without doubt, the most accurate for ordinary clinical work in the tropics, for in that position the thermometer is as completely as possible protected from the influence of the nose and the skin.

A thermometer, however quickly it reacts to its surroundings, must be left a reasonable time in the mouth, by which is meant two or three minutes, so that the temperature of the closed mouth may approach that of the rest of the body. Crombie gives the time for the accurate recording of the temperature in India as:

Ten minutes in the well-closed and dry axilla.
Eight minutes in the mouth.
Three to four minutes in the rectum.

The mean daily temperature of man for the hours 8 a.m. to 12 midnight in the Temperate Zone is:

98·45° F. (36·90° C.) in the axilla.
98·36° F. (36·87° C.) in the mouth.
98·96° F. (37·20° C.) in the rectum.

The so-called normal temperature of man, 98·40° F. (36·90° C.), in the mouth was determined as the mean temperature from 8 a.m. to 12 midnight by John Davy in 1837, and by some mistake has been interpreted into the mean temperature for the twenty-four hours, which is different, being probably lower.

Crombie gives the following as the means of the observations of Ogle, Allbutt, Casey, and Rattray:—

Mean Morning Temperature.	Mean Afternoon Temperature.	Mean Twenty-four Hours' Temperature.	Maximum Daily Range.
97·763° F.	98·341° F.	98·084° F.	1·41° F.

But at present there are insufficient data upon which to base a definite conclusion as to the mean temperature of human beings for the whole twenty-four hours.

The average temperature varies from between 96° F. and 97° F. to a little under 99° F. in the mouth, and the rectal temperature from 97·2° F. (36·28° C.) between 2 to 5 a.m. to 99·4° F. (37·45° C.) between 4 to 7 p.m.

EFFECTS OF TEMPERATURE AND HUMIDITY.

Atmospheric temperature and humidity must be considered together, because the effect of high air temperatures is modified by the humidity of the atmosphere.

The consideration of the effects of high air temperatures associated with varying degrees of humidity on man, may be conveniently discussed under the following headings:

1. Effect on digestion.
2. Effect on respiration.
3. Effect on the circulation and the blood.
4. Effect on bodily temperature.
5. Effect on the nervous system.
6. Effect on the urinary system.
7. Effect on the generative organs.
8. Effect on growth.

Effect on Digestion.

Parkes states that in warm climates the digestive powers are somewhat lessened, there is less appetite, less desire for animal food, and more wish for cool fruits. He, together with Marshall, Davy, and Morehead, believe that the quantity of bile excreted by the liver is not increased, though Lawson is of the opposite opinion.

While we agree with the fact that there is less appetite, and certainly less desire for animal food and more desire for hot or spiced food, and probably not such good digestion, we are not in accord with the writers who maintain that there is normally hyperæmia of the abdominal organs in Europeans and Natives alike in the tropics. There may be hyperæmia, but it is pathological, not normal. There may be an excess of bile secretion, but this will depend upon the food and drink, especially the latter if alcoholic.

Effect on Respiration.

Rattray studied very fully the influence of tropical climates on respiration, and gives a table showing their effect on the capacity of the chest, as indicated by the spirometer, on a voyage from England to Bahia and back. The average of twelve observations is as follows (hygrometer indicates the difference between the wet and dry bulb of a Mason's hygrometer):—

Number of Persons, 12.	Temperature 65° F., Hygrometer 2·5° F.	Temperature 78° F., Hygrometer 4° F.	Temperature 83° F., Hygrometer 4° F.	Temperature 65° F., Hygrometer 1·5° F.
Capacity of the chest as shown by spirometer ..	256·083	280·75	287·416	260·25
Gain or loss	—	+ 24·833	+ 6·5833	− 26·333
Percentage gain ..		12·24		—

The increased capacity, according to Rattray, is not due to any actual increase in the capacity of the size of the chest, but to a diminished quantity of blood in the lungs, which he considers has been diverted to the excited and congested skin and liver.

His results may be summarized by saying that the vascularity of the lungs is reduced by 23 fluid ounces, and owing to diminished number of respirations 7·5 per cent. less air is used daily, and 1·1 ounces less carbon, and 4·5 per cent. less aqueous vapour excreted.

With regard to these observations of Rattray, he is apparently supported by all observers as to the increase in capacity when Europeans enter the tropics. Jousset, however, states that this is only temporary, and disappears after acclimatization.

Rattray maintained that there was a diminution of capacity when a native of the tropics went to the Temperate Zone, and gave the following table :—

Condition.	Race.	Temperature 79° F.	Temperature 78° F.	Temperature 32° F.
B. C., aged twenty-one; height, 5 feet 5½ inches	Native of Sierra Leone	210	207	185
J. C., aged twenty; height, 5 feet 4 inches	Native of Sierra Leone	174	166	156
J. W., aged thirty-one; height, 5 feet 4 inches	half-caste	176	162	—

He found that the frequency of respiration was slower in the tropics, as is shown in the following table :—

Climate.		Mean Shade Temperature.	Highest Number of Respirations.	Lowest Number of Respirations.	Average Number of Respirations.
England	Summer ..	62° F.	18	13·5	15·68
	Winter.. ..	42·25° F.	17·5	15	16·50
Equatorial doldrums	Outward ..	78·74° F.	14·5	11	12·74
	Homeward ..	78·60° F.	15	12	13·74

Jousset, Plehn, and others controvert Rattray's statement that the respirations are slower, believing, on the contrary, that they are augmented before acclimatization.

This clearly shows that the question is far from settled, and, in fact, requires reinvestigation.

Effect on Circulation.

Rattray investigated the pulse-rate carefully, and gives the following table :—

Time.	Number of Observations.	Tropics				Temperate Zone.
		Lowest.	Highest.	Range.	Average.	Average.
9 a.m. ..	53	66	112	46	86·4	91·7
3 p.m. ..	53	68	108	42	88·8	88·1
9 p.m. ..	49	73	110	37	87·3	90·5
Averages	—	—	—	—	87·5	90·1

He gives the following conclusions :

1. The average pulse is lower by 2·5 beats in the tropics than in the Temperate Zone.
2. This change holds good for the average morning and evening pulse.
3. The average afternoon pulse is higher in the tropics than in the Temperate Zone, probably because the solar heat is greatest then.
4. The morning pulse has the greatest and the evening the lowest range.

He considers that this reduction in the pulse-rate is related to the diminished respiratory function. Parkes, Jousset, Crevaux, Feris, and Plehn, according to Huggard, maintain, on the contrary, that the pulse is increased by ten beats per minute. Plehn says, however, that on acclimatization the pulse-rate sinks to normal.

There is said to be a lowering of tension (associated, according to Huggard, with the dilatation of the peripheral vessels), as well as increased elasticity and dicrotism, all of which probably pass away on acclimatization.

In our experience, in Europeans coming to the tropics, the pulse-rate is *occasionally* slightly increased. This disappears after acclimatization, and the pulse-rate becomes the same as in Temperate Zones. We have never noticed dicrotism of the pulse in normal individuals.

As regards natives of the tropics, it is stated by some authorities that their pulse is quicker than in the inhabitants of Temperate Zones. We have not been able to confirm this statement. Their pulse-rate is the same as in Europeans.

The condition of the blood in Bengalees in India has been recently studied by McCay and his collaborators with the results shown in table on p. 57.

As a result of these researches, they conclude that these and many other differences met with in the Bengalee modify to no small extent the physiological condition of nutrition, growth, muscular power, and metabolism, and alter the reactions occurring in disease.

Nature of Observation.	Male Bengalees in India.	Europeans in Europe.
Erythrocytes	5,300,000	5,193,000
Leucocytes	9,000	7,500
Hæmoglobin (Haldane's method) ..	81	100
Colour index	0·74 to 0·85	0·95 to 1·1
Water	78·88	78·87
Total solids	21·12	21·13
Proteids	18·26	19·17
Salts	1·06	0·78
Blood-pressure in brachial by Riva Rocci's sphygmomanometer	100 millimetres Hyg.	110 to 130 millimetres Hyg.
Ratio of salts in the urine to those in the blood	1·2	2·0

McCay has shown that these changes are dependent not upon air temperature, but upon food, as has already been pointed out.

Effect on Bodily Temperature.

The discussion on the effects of heat and humidity on the bodily temperature may be subdivided into observations and experiments made in the Temperate Zone and those made in the tropics.

1. **Experiments and Observations made in Temperate Climates.**—These experiments began with Lining in 1738, who found that when the temperature in the sun was 125·9° F. (51·1° C.), and in the shade 98° F. (36·7° C.), his own axillary temperature was 96·9° F. (36·1° C.), and his mouth temperature 98° F. (36·7° C.).

Ellis in 1758 recorded a bodily temperature of 96·9° F. (36·1° C.), when the temperature of the air was 105·0° F. (40·6° C.).

In 1775 Blagden and Fordyce observed that in dry air in a room heated from 233·9° F. (115·5° C.) to 260° F. (126·7° C.) their temperature remained normal, as taken by the mouth and urine, even though beefsteaks were cooked by that temperature within thirteen minutes. These observations show that man can regulate his temperature to suit a high external temperature if the air is dry.

In a damp room with a temperature of 123·9° F. (54·4° C.) their temperature, however, was 100° F. (37·8° C.). There is, therefore, a great difference between the effect of dry and moist heat upon man.

The next series of experiments of importance on man are those by Haldane, who descended a hot, damp mine—the Levant Mine in Cornwall—in which the air was saturated with moisture and the temperature was from 80° to 93° F. (26·7° to 33·9° C.). In this mine he felt much discomfort, and even in parts at 86° F., or 30° C., found that his temperature rose to 102·5° F. (39·2° C.), and that of another member of the party to 101·5° F.

He also mentions that on Boycott's visit to a spot where the air was saturated and the temperature 93° F., the latter's mouth temperature rose to 103·5° F.

He says that, on the other hand, the men who are accustomed to the mine appear to bear the heat well, and not to suffer in health. But he remarks on the leisurely way in which they work, an observation which strikes the reader in the tropics very forcibly, as it compares with the slow progress of the work he sees done around him.

His preliminary conclusions were that the rectal temperature did not show any abnormal increase until the temperature of the wet bulb rose to 88° F. (31° C.), provided the subjects were stripped to the waist or clad in light flannel.

If the wet bulb exceeded this temperature by even 1°, a very marked rise in the rectal temperature took place, and this happened whether the air temperature was the same as the wet bulb, or 50° F. (28° C.), or only 10° F. above it. The rectal temperature rose hour by hour in proportion as the wet bulb temperature rose above 88° F., but more rapidly the higher this temperature rose.

If the experimenter was at rest in air moving at the rate of 170 linear feet (51 metres) per minute, a wet-bulb temperature up to about 93° F. could be borne without rise of body temperature. When he was working leisurely in still air, the limit of the wet-bulb temperature was 78° F. (25·5° C.), and with hard work it was lower. When he was working leisurely in air moving at the rate of 135 linear feet per minute, 85° F. (29·5° C.) could be borne, but not 87° F. (30·5° C.).

The symptoms which accompanied the abnormal rise of body temperature were:

(1) Marked rise of the pulse-rate about 20 per 1° F., or 36 per 1° C. rise in rectal temperature when standing, and a quarter less when sitting. This increase depended not merely on the rectal temperature, but also on the wet-bulb temperature, for on returning to cool air there was an immediate drop of the pulse-rate of 10 per 1° F. standing and 8 sitting.

(2) When a rectal temperature of 102° F. was reached, hyperpnœa was noticeable.

(3) Profuse sweating.

(4) General feeling of exhaustion and discomfort.

It is obvious, therefore, from the experiments quoted, that a normal man—for a short time, at all events—can stand very high temperatures without bad effects, provided that the air is dry. The skin is able to compensate for the excess of heat received by increased work, which it does by increasing the loss of heat by hyperæmia and increased sweat-production, for it must be remembered that loss due to radiation and conduction will be diminished.

If, on the other hand, the humidity of the atmosphere is increased, and a temperature of 88° F. in still air, or 93° F. in moving air, as recorded by the wet-bulb thermometer, is exceeded, the bodily temperature will begin to rise.

It is therefore obvious that, in discussing climatic effects, the relative humidity is of the utmost importance.

2. **Experiments and Observations in the Tropics.**—The tropical observations may be divided into—

(1) Observations during passage from the Temperate to the Tropical Zone.

(2) Observations during residence in the tropics.

(3) Observations during passage from the tropics to the Temperate Zone.

(1) *Observations during Passage from the Temperate to the Tropical Zone.*—Davy in 1839, during a voyage from England to Ceylon, made observations on seven healthy men under thirty years of age, the results of which were as follows :—

Climate.	Temperature of Air.	Mouth Temperature.
Tropics	79·5° F. (26·4° C.)	99·2° F. (37·32° C.)
Temperate Zone	60·0° F. (15·6° C.)	98·3° F. (36·80° C.)

From these data he concluded that the temperature of man increased in passing from a temperate to a warm climate, and that, therefore, the inhabitants of warm climates have a slightly higher temperature than those in temperate climates. Reynaud and Blosville's observations on the mean temperature of eight men are as follows :

Climate.	Temperature of Air.	Temperature of Men.
Tropics	79° to 86° F. (26° to 30° C.)	100° F. (37·58° C.)
Temperate Zone	53° to 62° F. (12° to 27° C.)	99° F. (37·11° C.)

Rattray, on a voyage from England to Bahia and back, took the temperature under the tongue thrice a day in a number of persons, and found :—

Climate.	Temperature of Air.	Mouth Temperature.
Temperate climate near England	65·0° F. (18·0° C.)	98·30° F. (36·8° C.)
Tropics generally	76·9° F. (25·0° C.)	98·66° F. (37·0° C.)
Equator	84·0° F. (27·7° C.)	99·02° F. (37·2° C.)

Rattray indicates that he noted the humidity, but unfortunately does not give figures suitable for making calculations as to the relative humidity.

According to Wunderlich, Brown-Séquard, on a journey from France to Mauritius, found the following changes in one week in the temperature of eight healthy people taken under the tongue :—

Climate.	Temperature of Air.	Mouth Temperature (Mean).
Temperate	46·4° F. (80·0° C.)	97·90° F. (36·625° C.)
Tropical	77·0° F. (25·0° C.)	99·40° F. (37·428° C.)
Equatorial	85·1° F. (29·5° C.)	100·22° F. (37·900° C.)

Eydoux and Souleyet, however, record smaller differences as the result of their observations.

Becher laid down as a law that the bodily temperature increased in the proportion of 0·05° F. for every 1° F. increase in that of the air.

Neuhaus, during a voyage round the world, took the temperature regularly, and found :—

Temperature of Air.	6 a.m.	12 noon.	6 p.m.	10 p.m.	
From 11·5°-13·6°	36·6° C.	36·9° C.	37·1° C.	36·8° C.	Rectal temperature
	55	55	62	56	Pulse
From 23·9°-26·6°	36·9° C.	37·3° C.	37·3° C.	37·1° C.	Rectal temperature
	60	68	72	64	Pulse

Plehn's observations on this point are of the greatest interest, for he found his temperature 0·9° F. (0·5° C.) higher than normal before acclimatization in the Cameroons, and 1·8° F. (1·0° C.) higher in the Red Sea, with a temperature varying from 80° to 89·2° F. (28·9° to 31·8° C.), with a relative humidity of between 60 per cent. and 74 per cent.

Further, he believes that on a quick transit from a cold to a hot climate the body temperature of a European undergoes a slight rise, which does not take place if the start is made in the European summer and the arrival in the tropics in the cool time of the year.

All these observers agree that there is a rise of bodily temperature in passing from the Temperate Zone to the Tropics, the rise being, according to—

Davy (mouth)	0·90° F. (0·50° C.)
Reynaud and Blosville	1·00° F. (0·47° C.)
Rattray (mouth) (tropics)	0·36° F. (0·20° C.)
,, ,, (Equator)	0·72° F. (0·40° C.)
Brown-Séquard (mouth) (tropics)	1·50° F. (0·80° C.)
,, ,, ,, (Equator)	2·32° F. (1·24° C.)
Neuhaus (rectal)	0·54° F. (0·30° C.)
Plehn (site ?)	0·9 to 1·8° F. (0·5 to 1·0° C.)

It would appear as though the bodily temperature increased about 0·5° F. on passing from the Temperate Zone into the tropics, but while provisionally making this statement, it is necessary to remember that the question of humidity has not been considered in comparison with these observations, which were all taken on board ship, many of them presumably in mid-ocean, where the relative humidity is considerable.

Rattray saw this defect in his own observations, and points it out in his last paragraph, and regrets that statistics are not forthcoming from which to draw satisfactory conclusions on this point.

Since he recorded his observations, Haldane's experiments have emphasized the importance of humidity, and personally we believe that Brown-Séquard's results still further demonstrate the need for more researches on this subject. Our own observations are in agreement on the whole with those who find no alteration, for records carefully taken on board ship have failed to show, with very rare exceptions, any rise of temperature in perfectly healthy Europeans entering the tropics for the first time.

The following table from Rattray clearly shows that a large number of records are necessary, otherwise individual differences will show too prominently :—

Time of Day.	Average Temperature of Air Shade.	Number of Observations.	Temperature 98° F.	Temperature 98·5° F.	Temperature 99° F.	Temperature 99·5° F.	Temperature 100° F.
9 a.m. ..	98·51° F.	51	22	11	11	7	0
3 p.m. ..	99·00° F.	51	6	5	18	17	5
9 p.m. ..	98·47° F.	51	8	23	15	5	0
Averages and totals	98·00° F.	153	36	39	44	29	5

It is therefore possible that Brown-Séquard's results may partly depend upon personal peculiarities.

(2) *Observations during Residence in the Tropics.*—The next point to discuss is the temperature of Europeans and Natives residing in the tropics.

The earliest observations to which we have referred are those made by Davy upon himself in England and Barbadoes :—

OBSERVATIONS ON HIMSELF IN ENGLAND FROM AUGUST, 1844, TO APRIL, 1845.

Time of Day.	Mean Temperature under Tongue.	Mean Pulse.	Mean Respiration.	Mean Temperature of Room.	Remarks.
7 to 8 a.m.	98·74° F.	57·6	15·6	50·9° F.	—
3 to 4 p.m.	98·52° F.	55·2	15·4	54·7° F.	Dinner at 5 p.m.
12 midnight	97·92° F.	54·7	15·2	62·0° F.	—

OBSERVATIONS IN BARBADOES FROM JULY, 1845, TO NOVEMBER, 1848.

Time of Day.	Mean Temperature under Tongue.	Mean Pulse.	Mean Respiration.	Mean Temperature of Room.	Remarks.
6 to 7 a.m.	98·07° F.	54·4	14·4	76·7° F.	Breakfast at 9 a.m.
12 to 2 p.m.	98·09° F.	56·0	15·4	83·6° F.	Dinner at 5 p.m.
9 to 11 p.m.	99° F.	60·3	15	79° F.	Tea, 7 p.m.

His own deductions are that the evening temperature was higher in Barbadoes by 0·93° F., and, further, that the daily fluctuations are not identical.

The next observations of importance are those of Crombie in Calcutta, who carefully investigated this question in Europeans and Natives of India during a period extending over eighteen months. The temperatures were taken in the axilla, mouth, and rectum.

The Europeans' temperatures were generally taken in the mouth, and the Indians' (because of caste prejudices) in the axilla, for which Crombie says a correction of 0·2° F. was made—*i.e.*, was added to these temperatures. The European figures are :—

Mean a.m. Temperature.	Mean p.m. Temperature.	Mean of Twenty-four Hours.	Maximum Daily Range.
98·21° F.	98·77° F.	98·49° F.	1·31

The average variation of the temperature in Europeans in India, according to Crombie, is as follows :—

2 a.m. to 7 a.m.	97·83° F.
8 a.m. to 1 p.m.	98·61° F.
2 p.m. to 8 p.m.	98·92° F.
8 p.m. to 1 a.m.	98·54° F.

It will be noticed that these figures make the European temperature about 0·41° F. higher in India than in England.

Food and exercise, but particularly the latter, produce a marked rise in temperature, which might last some hours. Sleep depressed the temperature.

With regard to Natives, the average temperature was found to be 0·50° F., and at noon nearly 1·0° F. higher than in a European.

Crombie points out that the high average temperature of the Native between 10 a.m. and 12 noon is probably owing to a meal between 9 a.m. and 10 a.m., and the absence of the rise in the evening to the fact that the temperatures were taken when at rest. He considers the normal temperature of Natives in India to be between 98° and 99° F. from 10 p.m. to 10 a.m., and from 99° to

100° F. between 10 a.m. and 10 p.m. In Ceylon and Africa, according to our experience, the temperature of normal Natives kept at rest does not exceed 98·4° F. Davy states that Natives of Ceylon, Mauritius, and the Cape have a temperature of 0·6° F. higher than the average in temperate climates.

Crombie and Davy both agree that the temperature of Europeans in the tropics is about 0·5° higher than in the Temperate Zone. In our experience this may occur, but only before acclimatization.

Livingstone noted that the temperature in the shade being 42·2° C., the native temperature was 36·7° C., while his own was 37·8° C. ; but this would without doubt be due to the fact that the natives would be perspiring much more freely than he was, because of the lack of clothes, for the skin of a perspiring West African native feels quite cold.

Jousset's observations, however, appear to begin to get to the real truth, for his figures demonstrate that though the axillary temperature is generally 0·7° C. to 0·8° C. higher in Europeans and Natives living in the tropics than that observed in temperate climes, they are approximately the same in both races under similar conditions of heat, humidity, etc.

Natives of the Tropics.		Europeans in the Tropics.	
Hindus	37·85° C.	Officials at Chandernagore	38·16° C.
Cochin Chinese	37·60° C.	—	—
Chinese	37·85° C.	—	—
Negroes of Senegal	37·70° C.	Sailors at Senegal	37·75° C.
Negroes on Congo	37·80° C.	—	—
Negroes at the Antilles	37·80° C.	Sailors at Antilles Soldiers at Antilles	37·70° C. 37·75° C.

Woodruff has tried to prove that blonde persons are more subject to increased temperatures in the tropics than brunettes, and states that variations as high as 100° F. to 102° F. have been noted in healthy blonde Teutons.

Eijkman, according to Pembrey, gives the average temperature of Europeans living in Batavia as 98·65° F. (37·02° C.), and that of the Malays 98·47° F. (36·93° C.).

It is thus seen that the majority of the above observers are inclined to the view that there is a slight increase in the temperature of Europeans and Natives in the tropics as compared with their Temperate Zone temperatures.

But Plehn's remarks on this subject are most interesting, for he says that after a residence in the tropics there is no difference between the temperature of a normal European in the tropics and that of a similar individual in Europe. Further, that there is no perceptible difference between the body temperature of the acclimatized European and the native black race.

These statements of Plehn are, in our opinion, the correct answer to the question we are considering—viz., that the acclimatized European and Native under similar circumstances have a similar temperature. He is supported by Johnston, Boileau, Furnell, and Thornley, and also by our own experience in various parts of the tropics. It is, however, obvious that further information is required on this interesting subject.

This position of affairs naturally brings us to the question as to whether there is a seasonal variation of the temperature in the tropics. Davy, as a result of observations upon his mouth temperature in Barbadoes, found no variations with the season. Jousset, on the other hand, found a drop of 0·2° C. to 0·3° C. in the average temperature of the Natives in the cool season. But these observations are too few to make any remarks upon, though one would expect such a variation.

Perhaps it will be found eventually that race has little to do with temperature, but that climate and possibly seasons in the tropics will be found to have an influence which possibly will depend largely upon the relative humidity of the atmosphere coupled with a high air temperature, care being taken in such observations to allow for the effects of exercise, food, clothing, sleep, etc. Moreover, individual differences may be considerable, as is well shown in Rattray's table given above.

(3) *Observations on the Passage from the Tropics to the Temperate Zone.*—Davy found that on passing from a hot climate to a temperate one, when there was a mean air difference of 20° F. (11·11° C.), there was a mean bodily temperature difference of 1·58° F. (0·88° C.).

Brown-Séquard, according to Wunderlich, found that when the party above mentioned had proceeded from the Equator to 37·4 degrees south latitude, the temperature of the air became 60·8° F. (16° C.), and the mean mouth temperature 99·04° F. (37·33° C.); but, of course, the party in question had not become acclimatized.

Ranke has made some observations on this point, but the total number are too few to enable any deductions to be drawn.

Our own observations indicate that there is no alteration in the temperature in the passage from warmer to cooler regions.

Effect on the Nervous System.

It appears that the cells of the nervous system obey the general law that vital activity is increased with a higher temperature, but only up to a certain point, after which their functional activity becomes markedly depressed. This is the case in most Europeans, though a great deal of mental and physical work can be done in the tropics if the bodily health is maintained. Natives naturally are less prone to feel the depressing effects of continuous high temperature.

It is possible that this condition, together with the effect of the actinic rays of the sun, may result in weakening the control of the higher centres over the lower, and thus inducing outbursts of what

Plehn calls ‘ tropical fury ’ (*Tropenkohler*), by which he means fits of passion caused by trivial incidents. This is seen not only in Europeans, but in Natives, who are apt to do violent deeds under the impulse of unreasoning anger. It appears to be one of the causes of assaults and violent crime in certain parts of the tropics.

Effect upon the Urinary System.

Urine is diminished in quantity in the tropics, and this is said to be due not merely to diminution of water, but also of solids, among which urea and chlorides may be noticeably mentioned. Lawson says that the pigments are increased.

It may, further, be of interest to note the results of McCay, Bannerji, Dutton, and Ghosal on the urine in Bengalees in India as compared with the European averages :

Constituent in the Urine.	Male Bengalees in India.	Male Europeans in Europe.
Quantity	1,177 c.c.	1,200 to 1,500 c.c.
Specific gravity	1006 to 1024	1015 to 1025
Urea	5·56 to 19·68 grammes per diem	30 to 35 grammes per diem
Total nitrogen	5·9 grammes per diem	14 to 18 grammes
Chlorides	9·43 grammes per diem	15 grammes per diem
Phosphates	0·95 to 1·4 grammes per diem	2 to 3·5 grammes per diem
N : P_2O_5 ratio	5 or 6 : 1	Practically the same
Uric acid	0·48 gramme per diem	0·3 to 7 grammes per diem
Total sulphates	1·75 to 2·2 grammes	2·5 to 3 grammes
Ethereal sulphates	0·15 to 0·22 gramme	—

McCay’s recent investigations show that this reduction in solids is due to the food, and not to the temperature.

According to Huggard, Dundas has described an atrophy of the kidney among residents of the tropics. We are well acquainted with the small size of the kidney so often seen in the tropics, due to chronic interstitial nephritis, but not with a simple atrophy of the kidney.

Effect on the Generative Organs.

The generative organs act more vigorously in the tropics, but venereal excess is distinctly more deleterious than in the Temperate Zone.

Menstruation begins about one year earlier in European girls living in the tropics than in those living in the Temperate Zone. For instance, it begins in 48·4 per cent. at thirteen to fourteen years of age, and in 50·07 per cent. at fifteen to sixteen years of age. Eurasian and East Indian girls, according to Das, mostly begin to menstruate at thirteen years (54·8 per cent.), though a considerable number do so at twelve years (18·6 per cent.). Natives of India mostly begin about eleven to twelve years of age (63·51 per cent.), and high-caste Indian girls begin in their eleventh year (50 per cent.) or twelfth year (48 per cent.) ; but this early menstruation may be associated with child-marriage rather than climate. Puberty in boys appears at an earlier age than in temperate climates.

There appears no reason to doubt that the climacteric is a more trying time for the European woman in the tropics, and tends to produce neurasthenia. If possible, therefore, such a woman should be sent to the Temperate Zone during this period.

It is probable that fertility is not affected in Europeans, though there is some doubt on this subject. Abortions are said to be more common in the European in the tropics than in the Temperate Zone, and post-partum hæmorrhage is also said to be more common, but these statements require careful investigation before being accepted.

Effect on Growth.

Rattray made observations on the weight and growth of forty-eight naval cadets, aged from fourteen and a half to seventeen years, during four successive changes of climate during a voyage.

He considered that they grew too rapidly and lost weight considerably in the tropics, and that their strength and health was impaired by the heat.

These conclusions of Rattray's are of the greatest importance, showing clearly the necessity (well known) of sending European children as soon as possible to live in the Temperate Zone, not merely, as some writers assert, for education, but, much more importantly, for their health.

McCay's observations show that too little proteid in the food affects the growth of the Bengalee boy, who grows up slender, and is defective in vigour and vitality.

THE EFFECT OF LIGHT.

Sunlight contains heat rays (red), light rays (yellow), and chemical rays (blue, violet, and ultra-violet).

These rays reach the earth, according to Langley, in the following percentages :—

	Per Cent.
Ultra-violet	39
Violet	42
Blue	48
Greenish-blue	54
Yellow	63
Red	70
Infra-red	76

The chemical rays appear to have, firstly, a stimulative and beneficial influence, and, secondly, a harmful influence.

Stimulative Influence.

Finsen, by experiments upon tadpoles, earthworms, beetles, flies, etc., came to the conclusion that the action of the chemical or blue-violet rays was very considerable as compared with light (yellow) or heat (red) rays, and that, though their action was probably very complex, still, it could be best considered as an excitation of the nervous system.

This excitation was so powerful as to produce reflex actions in tadpoles and movements in other animals, while in man he considers them to be the cause of the feeling of *bien-être* experienced on a bright, sunny day, which he compares with the depression felt on a dark, cloudy day.

Bactericidal Properties.

Downes and Blunt in 1877 showed that the chemical rays could kill bacteria, while D'Arsonval and Charrain showed that they could kill the *Bacillus pyocyaneus*. In 1903 Bernard and Morgan demonstrated that it was the middle third of the ultra-violet portion of the spectrum which caused these bactericidal effects.

Harmful Influences.

Acute Skin Irritation.—Charcot in 1859 first expressed the opinion that it was the chemical and not the heat rays which produced sunburn, and showed that the dermatitis caused by strong electric light was identical with that caused by the sun.

In 1889 Widmark proved this definitely by using an electric arc of 1,200 candle-power, the light of which was first passed through water to absorb the heat rays, and then allowed to fall upon the shaven skin of a white rabbit, when the characteristic inflammation resulted. He then interposed a plate of ordinary glass to exclude the ultra-violet rays, when the skin remained unaffected.

In 1901 Finsen placed on the flexor surface of his forearm a plate of rock-crystal and pieces of different-coloured glass, and also wrote his initials in Indian ink. He then exposed the arm to the rays from an 80-ampère arc for twenty minutes, ten minutes at a distance of 50 metres, and ten minutes at 75 metres. The result was that first all parts were slightly influenced by the heat, and then those parts which were unprotected or covered with rock-crystal became red and inflamed, and later desquamated and became pigmented, while the parts covered by glass and Indian ink, after the slight initial inflammation due to the heat, did not further react. This experiment is interesting as showing that the effects due to heat appear at once and pass off quickly, while those due to the chemical rays do not begin until after a lapse of three hours, which agrees with the well-known fact that a sunburn takes some time to develop.

Freund, as the result of his experiments, concluded that the chemical rays penetrated into the skin. Bernard and Morgan found that the ultra-violet rays were the active agent in producing sunburn.

The histology of solar erythema is not well known. Leredde and Pantrie made a biopsy on the skin of the shoulder of one of their friends who was suffering from sunburn of three days' duration. The skin was in a condition of acute erythema, without œdema or effusion. Under a low power of the microscope the epidermis appeared normal in thickness and disposition, but the horny layer was exfoliated in places. The dermis was richer than normal in cellular elements, and the connective-tissue bundles were swollen. Under a higher power the intercellular spaces appeared larger than normal. The vessels of the dermis were dilated, and there was a slight leucocytic infiltration, while the connective-tissue cells were swollen. These appearances are exactly like those produced by the rays of an electric light.

If the sun's action stops at this, the only change will be the deposit of the yellowish-brown pigment in the skin so well known in the tropics. If, however, the action is more intense, an exudation appears, which may be sero-fibrinous, cellular, or bloody, while the depth to which these changes may extend depends upon the intensity of the light. The epithelium becomes swollen, and bullæ may form, and the connective tissue of the dermis be swollen.

The pigmentation of the epidermis is important, and will be referred to at greater length in the next section.

Chronic Skin Irritation.—The chronic effects produced on the skin by the chemical energy of light are:

(1) Pigmentation.
(2) Vascular modification.
(3) Disease.

(1) PIGMENTATION.—It is well known that pigmentation follows sunburn, but until recently it was not evident that it was of a protective nature.

In 1888 Wedding, confirmed by Charcot, first made this point clear, though Unna in 1885 was the first to say that it was to be regarded as useful, inasmuch as it prevented the rays penetrating too deeply, thus preventing inflammation.

In 1896 Finsen painted a black ring 2 inches wide round his arm with Indian ink to imitate the colour of a negro's skin, and then exposed it for three hours to a very hot sun. For a time the skin remained normal, showing only a little redness at the edge of the black paint, but in due course it became red and inflamed, except where it had been painted black. After several days the erythema disappeared, and the area which had been red was noticed to have become distinctly pigmented, or, in plain language, was sunburnt.

He then exposed it again to the sun, but this time the area which had originally been covered with Indian ink was unprotected. The result was that this part became red and inflamed, while the pigmented area was unaffected, except that it became a little more pigmented.

This experiment of Finsen's shows that the colour of native races living in the tropics is protective, and was possibly originall induced by the sun. Sambon and Baly found that the ultra-viole rays were entirely absorbed by a pigmented piece of skin, an therefore support the theory that pigmentation affords an efficien natural protection against ultra-violet rays.

That the dark pigmentation is useful is shown also by the observation made by us on various occasions that natives sufferin from leucoderma avoid going into the sun, as they state that th unpigmented portions of the skin become inflamed and painful In this connection, an interesting case showing the importance o these rays came under our notice. A native, who had develope large leucodermic patches involving the whole of the face, notice that he could no longer work in the sun, as each time he tried t do so the patches became painful and he felt sick, very weak, an giddy, and therefore asked to be relieved of his outdoor duties ; bu it was held that the man was still fit to discharge his ordinary duties with the result that the unfortunate man was compelled to resig his appointment a few months later. It is therefore well that th importance of skin pigmentation should be more widely known.

Generally speaking, in regions where the sunlight is very intens the race is densely pigmented. As a rule, the people who liv nearer the Equator are more pigmented than those farther away *e.g.*, the black colour of the West African can be compared wit the red of the American Indian or the yellow of the Chinese. Bu this rule is not without exceptions, for the Sinhalese, living neare the Equator, are distinctly less pigmented than the Tamils of th warmer regions of Jaffna and South India.

There is also not the slightest doubt that the European living i tropical countries becomes darker, a fact which specially applies t the descendants of the settlers. On the other hand, according t Finsen, the dark colour of the negro diminishes to a sensible degre in Europe.

It must be noted, however, that a certain number of European do not become sunburnt in the tropics. On the contrary, thei skin, especially in localities where the climate is damp and hot may take a peculiar whitish colour, even in cases in which the bloo examination does not reveal any sensible decrease in the amount o hæmoglobin.

The effect of tropical light on man has been made the subject o a special memoir by Woodruff, who points out that all over th globe the people who live nearer the poles are blonder than thos residing near the Equator. He thinks that insufficient pigmentation, by permitting the penetration of the chemical rays, conduce to the increased activity of the mind and vigour in the muscle which is found in new-comers in the tropics. This condition o excitation causes them to overdo themselves sooner or later, and s to produce a feeling of exhaustion which he describes as tropica exhaustion.

He further considers that white men cannot become acclimatized in the tropics, and also that they should be protected by clothing opaque to the blue and ultra-violet rays. For this purpose he says that the outer clothing should be white, grey, or yellow, because heat will be least absorbed by these colours, while the underclothing should be black or yellow, to stop the ultra-violet rays. For office-workers and others not exposed to the direct sun rays he advises black or dark blue, but he states that it is not known whether blue or black excludes the ultra-violet rays.

He also strongly advises opaque head-gear, as he says it is surprising how transparent the scalp and skull are to light rays, and that it is certain that the ultra-violet rays pass through them.

He points out the nuisance of the glare from houses painted white in the tropics, and mentions the better colours of green, dark yellow, and brown. The gradual disappearance of the white buildings in the business part of Colombo, and the appearance of new buildings coloured brown, indicates the correctness of his views.

While it is not possible to agree with all or even with many of Woodruff's statements, there is no doubt whatever that there is a great general truth in what he says, though many of the matters upon which he touches are purely speculative. On the other hand, there is most urgent need for protection from sunlight both as regards the eyes and the whole body. There is not the slightest doubt that the pigmentation of native races is protective, and that the older theories of Waltz that carbon was deposited in the tissues owing to imperfect oxidation due to heat, and that of Darwin that it was due to a survival of those best fitted to withstand tropical disease—for he believed that pigmentation prevented the Native from being attacked by the fatal miasmata of the country—cannot now be seriously considered.

As to the origin of the pigment, this question must be considered as far from settled. There are two possible sources for the melanin —viz.:

(*a*) The hæmoglobin of the blood.
(*b*) The cells of the epidermis.

(*a*) *The Hæmoglobin.*—This theory suggests that hæmoglobin is altered into melanin either in the blood-stream, in the connective-tissue cells, or in special melanoblasts, which by amœboid movement take the pigment to the epidermis.

(*b*) *The Cells of the Epidermis.*—This theory states that melanin is manufactured *in situ* by the epithelial cells, and is not derived from hæmoglobin, and in view of the histology given above this appears to be probably the correct solution of the problem.

Melanosis, which varies from mere freckles through the diffuse yellow and brown pigmentation to the jet-black of the African negro's skin, is caused by melanin granules lying in and between the cells of the epidermis.

With regard to the pigmentation of different races, it must be remembered that it is only absent in albinos, and that it occurs in the epidermis of the areolæ and mammillæ of the breast, the scrotum, labia majora, and around the anus in white races, being contained chiefly in the large basal cells of the malpighian layer, and to much less extent in the more superficial layers, and the connective-tissue cells of the papillary layer of the corium. In negroes the pigmentation is deeper and more diffusely spread in the epidermis.

(2) VASCULAR MODIFICATION.—Associated with pigmentation there is said to be a persistent dilatation of the vessels and capillaries of the skin, and it is stated that hair and nails grow more rapidly in the tropics than in the Temperate Zone.

Light in general is believed to have an effect upon the blood, which absorbs the violet and ultra-violet rays, and the red corpuscles under these influences probably absorb more oxygen.

(3) DISEASE.—With regard to disease, there appears to be no reason to doubt that the irritating effect of light has at least a part in the ætiology of Kaposi's disease (*Xeroderma pigmentosum*).

We have met with this condition in the tropics, where it would naturally develop rapidly in children prone to the disease.

There is also no doubt that these rays are productive of the erythema of pellagra, as will be described later on, and they may have some effect in producing sunstroke.

Woodruff draws attention to the almost universal neurasthenia of white men in the tropics, among whom he says insanity is more common than in Temperate Zones. In support of the latter statement, he asserts that the insanity rate in the Philippine Army in 1901 was 2·02 per mille, while in the United States from 1889-98 it was 1·13; but he remarks that the diagnosis was not confirmed on the arrival of several of the Philippine soldiers in the United States, as they recovered *en route*. He draws attention to the loss of memory in the tropics (*tropical amnesia*), a condition which is very prevalent on the West Coast of Africa, being often called 'coast memory.' He also mentions the midday siesta as useful in preventing this neurasthenia, and in this he is also probably correct, especially for ladies. Ordinary officials and business men, however, cannot afford to rest in the middle of the day.

ACCLIMATIZATION.

Plehn seems to have been the first careful observer to clearly prove that the changes induced in the new-comer as he enters the tropics in due course disappear, and his organs becoming accustomed to the new work demanded from them, he virtually returns to the same condition of temperature, respiration, etc., as in the Temperate Zone—in other words, becomes acclimatized, though his organs are working quite differently, as has already been explained. Further, if constantly exposed to the sun's rays, his skin is apt to become more pigmented than normal, and to afford a certain degree of protection against its rays.

We are, therefore, of the opinion that if, as Sambon pointed out long ago, proper sanitary and other measures against disease were introduced into the tropics, and if care were taken with regard to food, drink, excessive heat, and the rays of the sun, there is no reason why the European should not live healthily in these regions.

We are supported in our belief by the extraordinary success of the American sanitarians in the canal zone of Central America, once one of the most unhealthy regions of the world, but where now the sickness-rate has been diminished to less than half that of the death-rate of many a tropical town. We feel that the basis of the largest proportion of illness and death in the tropics is bad sanitation, and not climatic influences. Notwithstanding these facts, a permanent colonization of the low-lying regions of the tropics by a white race is, in our opinion, not possible, as the climate greatly deteriorates the physique of the children.

PROPHYLAXIS.

An attempt has been made in the foregoing sections to impress the reader with the importance of the heat and the light rays in the tropics. It now remains to suggest easily applicable methods of prophylaxis to diminish these evil effects.

The remedies are :—

1. Protection for the head, spine, and eyes.
2. Suitable clothing.
3. Suitable houses, offices, etc.
4. Vegetation.
5. Suitable roads.
6. Avoidance of the midday heat.
7. Avoidance of alcohol.

1. **Suitable Head-gear.**—All Europeans should wear a light helmet or topee covered with white or khaki-coloured cloth externally and ventilated. This helmet should have a broad brim lined with green and prolonged down the back of the neck, and should be lined internally with red, or red and yellow, or black.

When persons are compelled to work under the tropical sun and to expose their backs to its rays, a spinal pad of yellow and red should be sewn into the shirt. Eyes should be protected with dark glasses with side-pieces.

Ladies who are particular about the skin of the face should wear black veils, though these are very warm.

The reasons of these requirements are that white reflects heat very well, and absorbs very little, and is therefore excellent externally; but it transmits the chemical rays, while red and yellow absorb them.

2. **Clothing.**—Clothing should be of a white or khaki colour externally, and black or coloured internally. The best cloth is the

'solaro' devised by Sambon, which is khaki-coloured externally and red internally.

It is made by using threads of yellow and blue twisted separately and together for the warp, while red threads are used for the weft, but these latter are brought back in the proportion of three to one, so that the front has three yellow and three blue threads to one red thread, thus producing the khaki colour.

It should be remembered that when clothing is wet it is a good conductor of heat, and hence the risk of sitting down in damp clothes. Clothing should not be too heavy, nor too tight-fitting. Ladies should not wear too heavy skirts, which congest the pelvic viscera.

A silk hat and frock-coat have still to be worn by men at official functions at midday, but the custom is unfortunate, and may perhaps in time disappear.

3. **Houses, Offices, etc.**—Buildings should never be painted white or blue, but should be of a dark red colour. The amount of light admitted to a room should be restricted, and care should be taken that reflection from the ground into the room does not take place. Deep verandahs, without which no building in the tropics is comfortable, are of the greatest value in controlling the light, as are tatties or tats made of grasses and wood, and jalousies.

Rooms should be capable of being cooled by fans, and should be lit with electric light whenever possible. Ice-blocks are very useful in very warm weather or at meetings, or in sick-rooms. The walls of rooms should be painted rose-colour, not white.

Damp courses are required in the tropics, as walls are apt to absorb moisture and become very damp. Round roof-tiles and ventilated double ceilings are necessary to keep off the sun's rays.

4. **Vegetation.**—Roads should be protected from the glare of the sun by shade-trees—that is to say, trees with spreading branches—while plots of green grass are most valuable in towns.

5. **Suitable Roads.**—There is not the slightest doubt that red roads are the most comfortable for the eye and soothing to the nervous system, and that white roads are exceedingly trying to both.

6. **Avoidance of the Midday Heat.**—If possible, travelling and muscular exertion should be done in the early morning or late afternoon, and avoided in the middle of the day, when a siesta is most beneficial. The absurd habit of making social calls at 12 noon in certain parts of the tropics should be discouraged, and a more reasonable hour substituted.

7. **Avoidance of Alcohol.**—Alcohol should never be taken before the sun goes down, for it unfits the individual for work, and is the most important predisposing cause of sunstroke.

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CHAPTER IV

INCIDENCE OF DISEASE IN THE TROPICS

General remarks—Ceylon—British Guiana—Straits Settlements—Jamaica—India—Egypt—Tropical Africa—China and Japan—Conclusion.

GENERAL REMARKS.

BEFORE beginning the systematic study of tropical diseases, a few remarks upon the difference in the incidence of disease in various tropical countries may be of interest. The factors which cause this difference are little known, and probably include many other matters than mere climatology—*e.g.*, sanitation, the habits and customs of the various peoples, and heredity, all of which must play no inconsiderable part in determining the presence or the preponderance of certain diseases in given places. Therefore it is convenient, at as early a stage in the book as possible, to present to the reader some brief statement of the diseases generally met with in different tropical countries, and at the same time to point out their incidence upon the different races dwelling therein.

In warm climates there are three distinct sets of human beings: firstly, those whose native habitat is a temperate or cold climate; these are classed under the term 'Europeans,' including Americans, Australians, etc., or, in brief, the white population: secondly, those who are natives of the particular climate; and if these consist of more than one race, it is convenient to divide them according to race: thirdly, the descendants from a mixture of European with a native race, such as Mulattos in Central and South America, the Eurasians in India, and the Burghers in Ceylon.

There are two methods of tracing susceptibility to disease—firstly, by sickness, and, secondly, by death-rates.

Any inquiry of this nature is, however, extremely unsatisfactory in the tropics, because disease is not as a rule diagnosed by a qualified medical practitioner; and because, unless care is taken, an erroneous diagnosis may easily be made by the latter; *e.g.*, even now typhoid fever, liver abscess, kala-azar, relapsing fever, tick fever, trypanosomiasis, glandular fever, undulating fever, agchylostomiasis, phthisis, empyema, appendicitis, and heat-stroke, are often diagnosed as malaria. It is also to be noted that in the official statistics of most colonies the list of diseases is far from being complete. Thus, for instance, the reader will fail to find such terms as ‘leukæmia,’ ‘pseudo-leukæmia,’ and even ‘elephantiasis’ in some reports. Then, again, such a common disease as agchylostomiasis is frequently mistaken for something quite different. Therefore the sickness-rates, which are difficult to get, are useless, as, indeed, are death-rates; in other words, statistics about disease in the tropics are most misleading. But with this understanding some remarks must be made; for though the figures are inaccurate, still, it is hoped that they will not continue to be so, but will slowly and steadily improve.

CEYLON.

The infantile mortality—*i.e.*, the proportion which the deaths of children under one year of age bear to a thousand births—is 175 per 1,000 births on an average, for the period 1898-1904.

This mortality affects the different races in the following manner:

Europeans	97
Sinhalese	157
Burghers	195
Tamils	213
Moors	230
Malays	292
Others	296

The principal causes, in official statistics, appear under the headings of infantile convulsions and diarrhœa, prematurity and debility, tetanus, bronchitis, and pneumonia; but the real causes are the bad condition of the mother before the birth of the child, improper and bad food, and lack of proper care of the child.

The crude death-rate of Ceylon for the period 1898-1904 is 27·4 per 1,000 inhabitants, and is divided racially—*i.e.*, per 1,000 of the racial population—as follows:

Tamils	31·1
Moors	29·3
Malays	28·1
Sinhalese	25·8
Burghers	22·0
Others	21·8
Europeans	21·1

Though the European death-rate is apparently low, still, it is undoubtedly high when it is considered that the population is, on the average, of an age on which death falls lightly in Europe; and, moreover, many of them have been medically examined before coming to the colony.

The principal causes of death are diarrhœa, dysentery, and the various kinds of fever, among which simple ill-defined fever stands highest. When this is considered, a strong suspicion is felt that it includes a great many cases of typhoid and paratyphoid, which only come to 5·2 per cent. of all diseases, while simple continued is 13·9 per cent.

So-called infantile convulsions come third, and probably agchylostomiasis ought to come high, because the figures for anæmia and dropsy, which often means undiagnosed agchylostomiasis, when added to the agchylostome rate, make 5·7 per cent. Malarial cachexia is often diagnosed when the true cause is agchylostomiasis.

Of tubercular diseases, phthisis appears to be the most important, and is apparently on the increase in the Sinhalese.

Cancer exists in all the races in Ceylon. Its lethal incidence, expressed as a percentage of the total racial deaths, is as follows :

Europeans	1·3
Burghers	0·7
Sinhalese	0·2
Tamils	
Malays	
Others	
Moors	0·1

The deaths of women in childbirth are higher than in Europe, and the principal cause is puerperal fever.

Diabetes is a prevalent disease among the better classes of Natives —among the lawyers, doctors, and merchants—but not in the lower classes.

Malaria in all forms is met with, but it is not a great cause of death, the pernicious form not being common. Simple tertian is the most common ; then the subtertian, and finally the quartan, which is the rarest of the three. Under the term 'malaria' have been placed kala-azar, leukæmia, and pseudo-leukæmia, which are far from being uncommon.

Insanity is relatively much less than in England and Wales or Ireland, the chief form being mania. It is notable that progressive paralysis, locomotor ataxia, and generally the parasyphilitic diseases, are extremely rare, though syphilis is rampant in all races.

Leprosy is common, but alone is not a great cause of death.

Beri-beri, although probably a Sinhalese word, does not exist in Ceylon, though a few imported cases die every year. Formerly cases were wrongly diagnosed, the disease referred to being really agchylostomiasis.

The principal causes of death in the different races are shown in the table on p. 78, which explains itself.

Ceylon has been rather fully dealt with, because figures are available which, however faulty, show to a certain extent the susceptibility of the different races to disease.

CAUSES OF DEATH IN THE RACES OF CEYLON EXPRESSED AS A PERCENTAGE OF TOTAL RACIAL DEATHS.

Europeans.		*Burghers.*		*Sinhalese.*		*Tamils.*		*Moors.*		*Malays.*		*Others.*	
Enteric	10·1	Phthisis	9·7	Diarrhœa	18·30	Simple Fever	17·3	Simple Fever	19·20	Simple Fever	10·4	Diarrhœa	9·5
Dysentery	10·0	Diarrhœa	9·3	Simple Fever	12·00	Diarrhœa	12·3	Diarrhœa	10·00	Diarrhœa	7·4	Dysentery	8·1
Phthisis	6·7	Pneumonia	6·6	Enteric	7·60	Dysentery	11·0	Dysentery	4·90	Phthisis	6·8	Simple Fever	7·4
Pneumonia	4·7	Dysentery	5·5	Phthisis	3·80	Pneumonia	6·2	Pneumonia	3·60	Pneumonia	5·9	Enteric	6·3
Diarrhœa	4·3	Enteric	3·4	Anæmia	3·60	Remittent	3·8	Phthisis	3·10	Dysentery	5·8	Phthisis	6·3
Simple Fever	1·7	Simple Fever	2·6	Dysentery	2·80	Malarial Cachexia	2·8	Enteric	2·70	Remittent	3·5	Remittent	1·9
Remittent	1·5	Remittent	2·3	Puerperal Convulsions	1·60	Phthisis	1·9	Anæmia	2·30	Enteric	1·5	Dochmius	1·6
Cancer	1·3	Child-birth	1·1	Child-birth	1·20	Anæmia	1·7	Remittent	1·60	Malarial Cachexia	1·5	Malarial Cachexia	1·1
Ague	0·6	Malarial Cachexia	0·8	Pneumonia	0·80	Child-birth	0·8	Child-birth	1·20	Child-birth	1·1	Pneumonia	0·9
Anæmia	0·4	Anæmia	0·8	Remittent	0·30	Enteric	0·7	Puerperal Convulsions	0·90	Puerperal Convulsions	0·9	Child-birth	0·6
Malarial Cachexia	0·3	Cancer	0·7	Cancer	0·20	Dochmius	0·7	Malarial Cachexia	0·80	Anæmia	0·8	Anæmia	0·6
Dochmius	0·2	Puerperal Convulsions	0·3	Malarial Cachexia	0·20	Ague	0·3	Dochmius	0·10	Ague	0·3	Ague	0·2
Child-birth	0·1	Ague	0·1	Ague	0·08	Puerperal Convulsions	0·2	Cancer	0·10	Dochmius	0·2	Puerperal Convulsions	0·2
Puerperal Convulsions	0·0	Dochmius	0·1	Dochmius	0·06	Cancer	0·2	Ague	0·09	Cancer	0·2	Cancer	0·
Total	41·9	Total	43·3	Total	52·54	Total	59·9	Total	50·79	Total	47·8	Total	44·9

BRITISH GUIANA.

For purposes of comparison let us turn to quite a different part of the world—viz., British Guiana—where the infantile mortality for 1905 is 187 per 1,000 births, which is racially divided as follows:

Chinese	93
Europeans	115
Aborigines	138
Mixed races	161
East Indians	166
Portuguese	215
Blacks	220

The principal causes of this mortality are malaria, undefined fever, bowel complaints, anæmia, debility, marasmus, premature birth, bronchitis, pneumonia, and convulsions. But, according to the Registrar-General, the great cause is illegitimacy; for the father, by refusing to support his offspring, compels the mother to work for her living, with the result that the child is looked after by anyone.

The crude death-rate is 27·4 per 1,000 of the population for 1905, the mean for the previous five years being 26·9.

The racial death-rates were:

Mixed races	19·8
Europeans	21·1
East Indians	25·6
Native blacks	29·2
Portuguese	31·9
Chinese	36·3
Aborigines	51·9
Africans	67·7

The principal causes of death appear to be: simple fever, convulsions, pneumonia, phthisis, Bright's disease, malaria, diarrhœa, dysentery, and bronchitis. Agchylostomiasis seems to have very little lethal effect, according to the figures. Cancer caused only 59, typhoid only 4, liver abscess only 9 deaths out of a total of 8,314. Leprosy was responsible for 69 cases.

STRAITS SETTLEMENTS.

Turning now to the Straits Settlements: the infantile mortality, after deducting immigrant deaths, is 256·29 per 1,000 births in 1905, and is racially classified as follows:

Europeans	57·32
Other nationalities	224·07
Malays	229·78
Indians	278·72
Chinese	302·03
Eurasians	307·69

The general death-rate of 40·51 per 1,000 inhabitants is racially as follows:

Europeans	20·73
Eurasians	30·92
Malays	34·33
Chinese	44·08
Others	46·63
Indians	46·93

The greatest number of deaths occurs in May, June and July, and between the ages twenty-five to thirty-five years.

The total deaths were 24,463, of which phthisis accounted for 3,015 (against 2,534 for 1904); beri-beri, 1,888 (2,287 in 1904); unclassed fever, 1,241; dysentery, 374; cholera, 20; malaria, 761; cancer, 56; anæmia, 43; sprue, 4; dropsy, 50; parasites, 15.

It will thus be seen that phthisis and beri-beri are potent causes of death in the Straits Settlements.

JAMAICA.

Turning next to Jamaica, the death-rate in 1906 was 21·9 per 1,000 inhabitants, while the infantile deaths amounted to 29·2 per cent. of the total deaths.

The principal causes of the crude general death-rate were fevers, phthisis, convulsions, influenza, malaria, dropsy, and parasitic disease.

INDIA.

In the Bombay Presidency the infantile mortality in native races is 220·08 in males, and 219·07 in females per 1,000 births. In Bombay City the ratios were 557·24 and 569·66, but it is stated that these ratios are very fallacious.

The racial death-rates are:

	1905.	1906.
Europeans	14·36	14·41
Eurasians	20·89	26·99
Natives	31·84	41·39

The year 1905 seems to have been unusually healthy; only 588,394 natives died, as compared with 1,318,783 in 1900.

The principal cause of death was plague, which accounted for 71,363, or 12·13 per cent., in 1905, as compared with 223,957, or 29·28 per cent., in 1904.

The plague deaths in Bombay for the ten years 1896-1905 are as follows:—

1896	2,086
1897	46,944
1898	86,191
1899	96,596
1900	33,196
1901	128,259
1902	184,752
1903	281,269
1904	223,957
1905	71,363
Total	1,154,613

The population in 1901 being—

European (exclusive of cantonments)	18,804
Eurasian	6,557
Native	18,481,362

the above figures will give the reader some idea of the mortality caused by the plague in India.

The next important cause of death is cholera :—

1896	35,404
1897	57,109
1898	4,368
1899	8,579
1900	163,889
1901	13,600
1902	3,229
1903	1,825
1904	13,156
1905	5,396

The general term 'fever' causes a mean of 310,420 deaths in the six years 1900-1905 ; most of this is supposed to be malaria.

The simplest way to show the Bombay death-rate is in the ratio per 1,000 inhabitants :

Cholera	2·11
Smallpox	0·26
Plague	9·18
Fevers	17·43
Dysentery and diarrhœa	4·90
Injuries	0·39
Other causes	12·12
Total	46·39

Respiratory disease in 1904 caused 3·22, and in 1905 2·95, deaths per 1,000 of the population.

The Bombay death-rate indicates clearly the incidence of cholera, plague, and fevers. In many parts of India—*e.g.*, Madras—kala-azar is an important death-producing factor. In Calcutta, phthisis is causing some apprehension by its increase. The importance of snake-bite as a cause of death is marked in India. Relapsing fever is also known.

EGYPT.

Egypt is interesting, because its diseases have been for many years carefully studied by competent observers. Typhus, Mediterranean fever, infectious jaundice, glandular fever, plague, bilharziosis, agchylostomiasis, pellagra, and relapsing fever may be noted among its diseases.

The death-rate for the period 1901-06 is, on an average, 34·7 per 1,000 Egyptian inhabitants, and of these deaths no less than 64·8 per cent. take place under the age of ten years, and 51·4 per cent. under the age of two years.

The principal causes of death are: dysentery and diarrhœa, congenital and senile debility, tuberculosis, infectious diseases, and violence.

TROPICAL AFRICA.

The West Coast of Africa has a high rate of mortality from malaria, and here the pernicious forms are not uncommon. Black-water fever is also a cause of death. The Guinea-worm is a very common cause of sickness.

In Uganda, the Congo, and the regions of British and German East Africa, trypanosomiasis abounds, and causes high death-rates.

Tick fever, apparently, is not a great death-producing disease.

CHINA AND JAPAN.

China and Japan and the neighbouring islands appear to be endemic areas for trematode diseases, as well as for beri-beri.

CONCLUSION.

It will thus be seen that disease appears differently in various tropical climates, but the geographical distribution will not be further considered here, but will be described for each disease separately.

The questions which the reader should try to solve, when working in a tropical country, are these:—

1. What are the principal causes of death in the country?
2. Are they properly diagnosed, or are important and well-known diseases being missed?
3. Are there diseases which as yet have not been recognized?

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PART II

THE CAUSATION OF DISEASE IN THE TROPICS

SECTION A

PHYSICAL CAUSES OF DISEASE

CHAPTER V

THE PATHOLOGICAL EFFECTS OF HIGH AIR TEMPERATURES

General Remarks—Thermic fever—Heat syncope.

GENERAL REMARKS.

THE most important physical cause of disease in the tropics is hig atmospheric temperature. A good method of studying its effect is by making observations in the hottest portions of the engine room of a steamer in the tropics, especially in the Red Sea.

The air of the engine-room is laden with aqueous vapour, an certain corners can be found where there is no draught, and there fore the conditions are analogous to those under which Haldan performed his experiments.

If a person, lightly clad and in good health, places himself i such a corner, with a clinical thermometer in his mouth, it will b found that at first he begins to sweat violently, and for a tim remains at a normal temperature. But in due course his temperature will gradually rise and his pulse-rate increase, until temperature of over 102° F. are reached, and the person breaks off the experiment because he feels uncomfortable, after which his temperatur slowly returns to normal.

We have performed this simple experiment several times, but o one occasion, in a person who was not in very good health, th temperature, after reaching 101° F., ceased to rise ; the skin becam cooler, the tension of the pulse altered remarkably, and he bega to look ill. The experiment was quickly stopped and stimulant administered, so that he did not suffer any serious effects, thoug it was some hours before he felt quite right.

These two experiments show that a high atmospheric temperatur can act in two ways. In the first there was a gradual rise of the body temperature, which, if continued long enough, would probably have resulted in hyperpyrexia. In the second, after an initial rise, the heart became embarrassed, and if the heat had been continued, there appears no reason to doubt that this person would have passed into a condition of syncope.

There are, therefore, two distinct clinical entities to be considered —viz., thermic fever, characterized by high bodily temperature; and heat syncope, in which there are symptoms due to cardiac failure but no fever—both of which are brought about by the same cause—viz., high atmospheric temperatures.

Both of these clinical conditions in our experience may also be caused by rays coming directly from the sun.

The earliest experiments, with a view to ascertaining definitely whether there is such a condition, were those by Scaghosi on rabbits exposed to the Sicilian sun. Their temperature rose considerably, and if the experiment was continued long enough they died, but if it was stopped they recovered. The post-mortem changes were hyperæmia of the meninges, heart, lungs, liver, and spleen. The nerve cells of the brain and spinal cord showed coagulative necrosis and chromatolysis.

The next experiments of importance on the ætiology of this condition are those of Möller on rabbits, who showed that thermal rays, with or without chemical rays, if directed on to the skin covering the skull, produced more or less intense cerebral disturbance, and sometimes even sudden death. The autopsy after intense irradiation showed the skin of the head much swollen and bloody, with gelatinous exudation in the subcutaneous tissue. The periosteum, cranial bones, and dura were discoloured, and covered with ecchymoses. The vessels of the brain surface were much dilated, and showed numerous, and in part confluent, ecchymoses.

We have performed a few experiments on rabbits, which show that if such an animal with its head shaven is exposed to the sun in Colombo about twelve noon, it dies with all the symptoms and post-mortem appearances of sunstroke in about sixty-seven minutes; whereas another rabbit similarly treated, but protected by red glass, lives. The ultra-violet rays seem to have no effect, and it would appear as though the active rays were in the visible blue and violet.

It seems, therefore, possible that direct sunlight can bring about (1) sudden death, and (2) congestion of the meninges of the brain.

The connection between sunstroke and the chemical rays has been ably brought forward by Duncan and others, but the whole subject requires more investigation. There is, however, no doubt that if the head, improperly protected, is exposed to the sun, there is often headache and a feeling of illness, and therefore adequate protection is most necessary.

Sambon thinks that an acute specific fever which he calls 'siriasis' is being confounded with heat-stroke, and this is possible; but we have not met with the condition.

Such are our views; but it is as well for the reader to be acquainted with those of other authors, which may be briefly state in a historical account as follows:

High air temperatures, whether in the day-time or at night, have been know since ancient times to have an effect upon human beings. The case of th child of the Shunamite woman described in the English Bible in 2 Kings iv. from verse 18 onwards, is probably the earliest on record. The child complained to his father of his head when out with the reapers, and was carrie to his mother, and is reported to have died at twelve noon—became insensibl —but recovered under Elisha's treatment, which appears to have been of th nature of massage. This treatment reminds one strongly of the activ friction by which the miners of the Comstock Silver Mines of Nevada are sai to successfully treat those of their fellows who faint when coming out of th warm mine in which the hot, steamy air has a temperature of 128° F.

It has been said that though old writers such as Dio Cassius described thes conditions, the medical writers of ancient times were silent about them This does not seem to be quite just, for Paulus Ægineta, Oribasius, and th Arabians certainly understood that there were head symptoms which the called 'siriasis' (after Sirius, the dog-star), due to excessive heat. Certainl this knowledge was lost, and Cardamus, in the sixteenth century, describe symptoms due to morbus attonitus (apoplexy) brought about by the heat an drought of the summer of 1543 in Florence. After this for a long time th disease was considered to be an apoplexy till Boerhaave, early in th eighteenth century, introduced the name 'insolatio,' and considered it to b a phrenitis—*i.e.*, meningitis.

Steinkühl (1819) thought that the congestion of the lungs caused death b asphyxia; Swift (1854) that it was due to exhaustion produced by fatigue Hill (1857) evidently confounded pernicious malaria and heat-stroke. Levick (1859) suggested that it was an acute specific fever; H. C. Wood (1863) considered that it was due to a poison developed in the blood, and called i thermic fever; while Stiles (1864) performed experiments on animals, an concluded that the disease was due to the direct effect of heat on the muscula system.

In 1869 Eulenberg and Vohl stated that the disease was due to sudden liberation of the gases in the blood; and Weikard and Richardson attribute it to clotting of blood in the vessels.

In 1870 Vallin performed several experiments by locally heating parts o the body, and concluded that there were two conditions: (1) sthenic insolation due to coagulation of the muscle fibres of the left ventricle; (2) asthenic insolation, due to the action of heat on the nerve centres of the brain, thus disturbing the innervation of the heart.

In 1871 and 1872 Claude Bernard performed some experiments which tended to show that when a warm-blooded animal died as the result of heat, it was due to rigor in the musculature of the heart.

In 1872 H. C. Wood performed experiments which showed that sunstroke could be produced in animals as readily as in man by artificial or natural heat. He came to the conclusion that death took place from asphyxia, and that after death the rigidity of heart and muscles was due to the coagulation of the myosin, and he further pointed out that this will take place at once in the heart if the temperature of the body reaches 115° F., and said that he considered it to be the cause of sudden deaths in soldiers in battle. Further, he pointed out that the heating of the brain of a mammal to 108° F. produces insensibility with or without convulsions, and that when 113° F. was reached the animal died, and that, though the general symptoms of sunstroke were absent, the nervous symptoms were present. He came to the conclusion that no capillary thrombi were formed, that no poisons were generated in the blood, and that the real condition was the heat acting upon the nervous system, as a result of which there was rapid metabolism, which used up oxygen and at the same time induced brain changes, causing asphyxia. But he distinguished from the true heat-stroke:

1. Acute meningitis or phrenitis, due to exposure to the sun, in which he disbelieved.

2. Heat exhaustion, due to working in a heated atmosphere, which he said did not differ from acute exhaustion due to other causes, and therefore was not true sunstroke.

In 1879 Jacubash classified heat accidents into: (1) sunstroke due to the action of the sun on the body, when the temperature may reach 113° to 115° F. (45° to 46° C.); (2) heat-stroke, due to exertion, and often seen in marching troops in the Temperate Zone; (3) thermic fever, which he considered to be the true heat-stroke of the tropics, due to accumulation of heat in the human body in consequence of high atmospheric temperatures without exposure to the sun or muscular exercise.

Dony (1884) considered that there were two main conditions: (1) sunstroke, due to the sun's rays acting upon the cranium and brain, only without very great rise of temperature; and (2) heat-stroke, due to intense heat acting on the whole body and after certain prodromes, resulting in a rapid rise of temperature to a great height.

In 1893 Saquel classified the diseases into (1) sunstroke, meaning the erythema due to the sun's rays; and (2) insolation, meaning the action of the sun on the nervous system, producing either congestion (mild form in the Temperate Zone) or meningitis and encephalitis (severe form in the tropics); (3) heat-stroke; and (4) thermopeliosis, a combination of insolation and heat-stroke.

In 1898 Sambon defined heat exhaustion as an ordinary syncope, while he considers that under the term 'sunstroke' there is confounded an infectious fever which he calls 'siriasis,' due to some micro-organism as yet not defined.

In the period 1898-1907 Sir Patrick Manson, in his book on tropical diseases, recognizes three conditions: (1) heat exhaustion—sudden cardiac failure or fainting, brought about by exposure to high atmospheric temperature; (2) siriasis, an acute disease developing in the presence of high atmospheric temperature, and characterized by sudden incidence of hyperpyrexia, coma; and (3) sun traumatism, or direct action of the sun's rays on the tissue, causing either sudden death or a febrile condition.

In 1905 Van Brero, in Mense's 'Handbuch der Tropenkrankheiten,' recognizes (1) heat exhaustion, due to excessive heat from the sun or other source; and (2) sun traumatism, caused by the direct action of the sun's rays.

In 1907 Sir Joseph Fayrer, in Allbutt and Rolleston's 'System,' recognizes (1) a state of exhaustion leading to syncope, and (2) an overheating of the nervous centres, blood, and tissues, leading to thermic fever.

In 1908 Brook defines diathermasia as the effect of heat on the thermotaxic mechanism, and phœbism, a kind of shock due to the actinic rays from the sun.

It will thus be seen that authorities in general recognize the action of heat and the action of sun's rays as being separate, and, further, that heat may produce a syncopal condition or fever, while the sun's rays may also cause syncope and fever. Some few, including especially Sambon, suspect the presence of an acute specific fever as being concealed in the diseases above mentioned. Others, again, consider the symptoms to be toxic in origin, so that there are four theories: (1) caloric; (2) actinic; (3) microbic; (4) toxic. Whatever the ætiology may be, we distinguish two clinical entities—viz., *Thermic Fever* and *Heat Syncope.*

THERMIC FEVER.

Synonyms.—Heat-stroke, sunstroke, sun traumatism, insolation, siriasis (not Sambon's siriasis), coup de chaleur (Fr.), coup de soleil (Fr.), Hitzschlag (Ger.), Sonnenstich (Ger.), colpo di sole (Ital.).

Definition.—Thermic fever is caused by a high air temperature, especially when associated with marked humidity, and is characterized by high fever and often extreme pulmonary congestion, convulsions, coma, and death.

This is the form of sunstroke and heat-stroke which we have commonly met with in the tropics.

Climatology.—The tropics are the principal seat of the complaint, and of these India appears to be the most important, and in it the Punjab, Sind, and the North-West Provinces are the worst, as can be judged by a reference to their climatology.

In Ceylon sunstroke is said to be much less common than in India. Thus in 1903, according to Sir Joseph Fayrer, in statistics given to him by Surgeon-General Sir A. Keogh, there were 303 cases in India among the European troops, with 53 deaths ; and in Ceylon 11, with 2 deaths, the total for the British Army for that year being 385 cases and 61 deaths.

In Asia it is well known in the Red Sea, the Persian Gulf, Burma, the Straits Settlements, South China, and Cochin China. In Africa it is met with in all parts of the tropical region. It is common in Mauritius, and is also well known in the United States, Canada, Nova Scotia, New Brunswick, and the West Indies. In South America it is met with in Guiana, Brazil, Peru, and the Argentine. In Australia it has also been recognized, and in Europe in summer. It is, of course, associated with the warm seasons in all countries, and with either very high air temperatures in relatively dry climates, or with not so high temperatures if there is much atmospheric humidity.

The disease stands in direct relationship to heat-waves, as has been pointed out by Rogers in India—a fact well known in temperate climates.

Ætiology.—The causation of the disease is the action of high air temperatures associated with a high relative humidity on man, which generally act during the day-time, but may also have an effect at night.

It has already been pointed out that a human being can—for a short time, at all events—stand a very considerable amount of dry, but not moist, heat. The heat regulation of the body is disturbed and the loss of heat prevented by the humidity ; consequently the body temperature rises.

Haldane's experiments have shown that if the wet bulb thermometer rises to 88° F. (31° C.) in still air, or to 93° F. (34·4° C.) in air moving at the rate of 170 feet (51 metres) per minute, or to 78° F. (25·5° C.) with leisurely work, some pathological effects appear and the temperature of the body begins to rise. It is of interest to note that the temperature of the body, instead of rising to a certain height with a given atmospheric temperature and then remaining stationary, in Haldane's experiments went on rising ; and in some measure this corresponded with the temperature of the air.

Thus, with reference to the rectal temperature, which is the best indication of the true bodily temperature, Haldane found that with a wet bulb at 89° to 90° F. the rise was 1° to 1·4° F. (0·5° to 0·75° C.) per hour; at about 94° F. (34·4° C.) it was 2° F. (1·1° C.) per hour; at 98° F. (36·4° C.) it was about 4° F. (2·2° C.) per hour.

If this condition can be induced in healthy persons at rest in England, it does not seem impossible or improbable that lower temperatures may act as vigorously or more vigorously upon Europeans in the tropics or elsewhere, especially if living under conditions of poor bodily health and bad sanitation, or if they are improperly clad or exhausted mentally or physically.

The fact that new-comers are more apt to suffer than old residents has been put on an experimental basis by Rosenthal, who has shown that a kind of active immunity to heat can be established by repeated exposure of an animal to a temperature lower than that which would have been fatal. These animals, when subsequently exposed to a very high temperature, do show symptoms, but they are less marked, the rise in temperature is not so high, the respirations and the pulse not so accelerated, and the general distress less.

The effect of clothing, load, and exercise has been calculated by Zurtz and Schomberg, who estimate that a resting soldier weighing 70 kilogrammes produces from 1·2 to 1·3 calories per minute; and when marching, with a load of 31 kilogrammes, produces 7·73 calories per minute, which will raise the temperature of the body 1° C. in 8·7 minutes. Under ordinary circumstances the soldier is not affected, but if he is wearing thick, tight-fitting uniform (especially in the old days of stocks), with a tight belt and knapsack with cross-belts, and is at the same time marching in close formation (when the air must certainly be impure from carbon dioxide and dust) under a tropical sun, it is obvious that, especially if there is a fairly high relative humidity in the atmosphere, he cannot get rid of this heat, and there is bound to be either thermic fever or heat syncope in a certain number of cases.

Predisposing Causes.—Thermic fever is, if anything, more common among children than adults, but it is very liable to be mistaken for other diseases. It is more common among men than women, owing to the greater exposure of the former. Among men it is principally found in stokers, and in soldiers during exhausting marches. Among soldiers the classical instance often quoted is the account of the march of the 43rd Regiment in the Indian Mutiny for over 1,100 miles, mostly across the plains of India, in the hottest weather.

The men remained quite well for 969 miles, when they became exhausted, and even emaciated; but in the narrow Kowri of the Bisramgunge Ghat, when the temperature in the tents ranged from 115° to 127° F. in the day, and on one occasion was 105° F. at midnight, they suffered severely, and two officers and eleven men died in four days, and later on seven more died in three days.

There is no doubt that exhaustion and unsuitable clothing were formerly the great causes of the frequency of attacks of heat-stroke in the army.

Race appears to have a certain amount of effect, for it is more common in Europeans than in negroes or East Indians, though it is met with in all. Previous illness is a great predisposing cause. Hot winds help to induce this condition; in India the hot wind 'loo marna' is much dreaded by the natives. Of all predisposing causes, alcohol is probably the most important.

Pathology.—Turning now to the effects of a raised internal temperature on the organs of a man, there are experiments to guide us.

Marinesco has shown that a temperature of 47° C. is immediately fatal to animals, while a temperature of 45° C. kills in one hour, and one of 43° C. after a longer lapse of time, the essential pathological change being chromatolysis in the nerve cells, therefore high bodily temperature may cause acute serious nerve-cell changes.

But the effect of high internal temperature has been further investigated by Halliburton and Mott, who have shown that a temperature of 47° C. (117° F.) is the coagulation temperature of neuroglobulin; while Hewlett had previously shown that egg-white would coagulate at a much lower temperature than usual if this is maintained for some time. His experiments were repeated by Halliburton and Mott on cat's brains, and they found that at 42° C. (108° F.) the neuroglobulin would separate out, but not at lower temperatures. Cat's brains kept at 42° to 43° C. for three and a half hours showed chromatolysis in the nerve cells. They therefore came to the conclusion that a coagulation necrosis takes place in the nerve cells, due to the coagulation of the cell globulin, and that when this occurs the protoplasm is destroyed.

Our own observations entirely agree with those of Marinesco, Mott, and Halliburton. Fig. 12 shows a nerve cell in a condition of coagulation necrosis with disappearance of the Nissl bodies from a case of sunstroke in which no pathogenic micro-organisms could be found post mortem. It appears probable, then, that the seat of the lesion of thermic fever is in the cells of the cerebro-spinal nervous system, and particularly those of the medulla.

Morbid Anatomy.—The body retains a high temperature for some hours after death; rigor mortis comes on quickly, and passes off quickly, and decomposition, on account of the high atmospheric and body temperatures, sets in. Lividity is well marked. The blood is dark, fluid, and acid. The brain and membranes are congested, and there may be minute hæmorrhages in the white matter, and marked increase of fluid under the membranes and in the ventricles. Microscopically, the minute vessels, especially of the medulla, are very congested, and the nerve cells show coagulative necrosis and disappearance of the Nissl bodies, together with a swollen and chromatolytic condition of the nucleus, though the nucleolus may remain apparently intact.

The organs of the body are in general congested, but especially the lungs, which appear almost black. The heart is often in a state of marked rigor mortis.

Symptomatology.—Sometimes the symptoms come on suddenly;

but more frequently there are prodromata. The patient often complains of feeling out of sorts and weak, especially in the legs, together with headache and drowsiness, and sometimes of nausea. Longmore lays stress on a frequent desire to micturate as a prodromal sign of importance, because, as mentioned by Simpson, perspiration is diminished or stopped, and the bowels are constipated, while the urine is copious and limpid.

Intolerance of light and chromatopsia—red, yellow, or green spots, with suffusion of the eyes—have been noted.

The attack begins with a sudden sharp rise of temperature to 104°-107°-110° F., while the skin becomes dry, burning, and flushed, with occasionally a macular eruption.

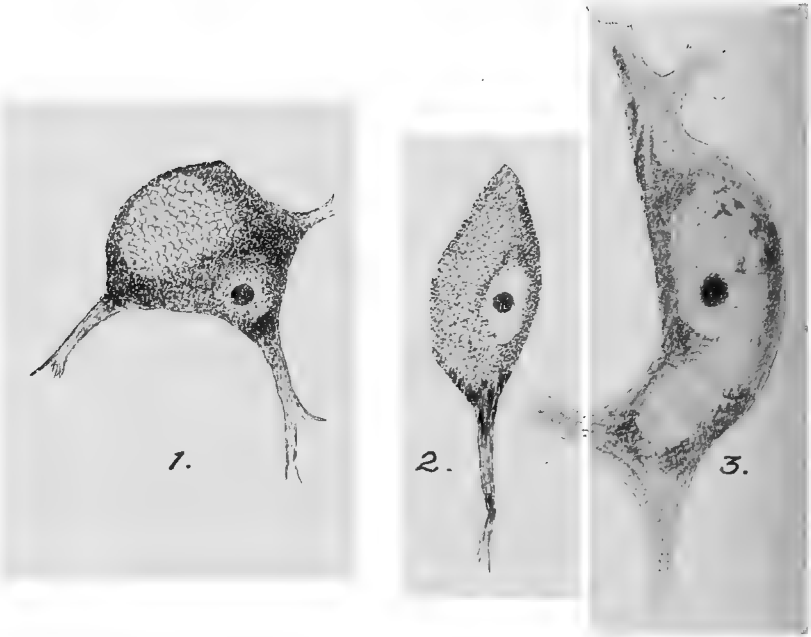

Fig. 12.—Nerve Cells from the Medulla of a Case of Heat-Stroke, showing Chromatolysis.

The patient becomes unconscious, delirious, or comatose, usually the latter. The pupils are often very contracted. The respirations are noisy and quick, and râles and rhonchi are heard on auscultation. The pulse is rapid, and though at first of good volume, soon becomes irregular, intermittent, and thready. The urine is scanty, and may contain albumin and casts. The motions are passed involuntarily.

If the patient is going to die, convulsions appear, and the skin becomes cyanosed and clammy; the respirations become slower and slower, and more and more stertorous; the pulse weaker and weaker, until the patient dies of asphyxia after an illness varying from a few hours to a day or so.

If recovery is to take place, the temperature often falls rapidly by crisis, the respirations become quieter, the pulse slows, there is a critical discharge of urine, and the patient falls asleep to awaken much better.

In some cases the course of the fever is much longer (see Fig. 13), lasting eight to ten days. Possibly this is due to secondary infection with intestinal bacteria. The patient remains very susceptible to high atmospheric temperatures for a long time after recovery.

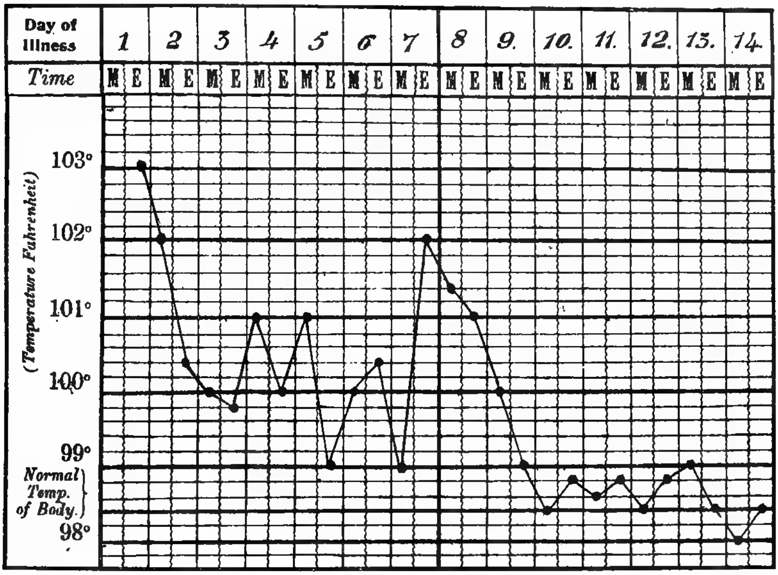

FIG. 13.—TEMPERATURE-CHART OF A CASE OF HEAT-STROKE IN A STOKER WHILE WORKING IN THE ENGINE-ROOM OF A STEAMER IN COLOMBO HARBOUR.

Temperature 103° F. three hours after the onset.

Diagnosis.—Thermic fever must be diagnosed from pernicious malaria by the absence of parasites in the blood; from cerebrospinal fever by the absence of Kernig's sign; and absence of contracture of the muscles of the neck. The high temperature should enable it to be differentiated from alcoholic or renal coma, as well as from apoplexy and epilepsy (in both of which the temperature may be slightly raised).

Prognosis.—The death-rate varies, as a rule, between 15 per cent.

Treatment.—Loosen the clothing at once, and remove the patient to as cool a place as can be found, and take off his clothes, and, if possible, lay him on a bed covered with a large indiarubber sheet, and apply an ice-bag to the head, while pieces of ice are rubbed over the body, and at the same time cold sponging is carried on. Also give large enemata of iced water.

While this is being done, friction should be applied to the parts which have been rubbed with ice, in order to promote circulation in the cooled skin.

If there is no ice, wring out a sheet in as cold water as can be found, and allow water to drip on the patient all over.

In places where no cold water is available, the ordinary water can be chilled by dissolving a fair quantity of salt in a bath of water, squeezing the juice of some limes into this, and then adding a quantity of vinegar and a little eau-de-Cologne, and sponging the patient with this mixture.

The danger in cold sponging is collapse; consequently the temperature must be carefully watched, and when it falls in the rectum to about 101·6° F. sponging must be stopped, and the patient covered up with blankets.

If the temperature comes down with a run and collapse sets in, treatment must be applied as described under Heat Syncope. The patient must in any case be carefully watched, and ice, cold sponging, or both, must be resorted to again and again till the temperature remains down.

If the fever is not reduced by this treatment, and the pulse is bounding, the body cyanosed, and the heart's action embarrassed, the median basilic vein may be opened and the patient freely bled; but if little or no blood comes, then an intravenous injection of normal saline at 98·6° F. (37° C.) may be run in.

Antipyretics are useless, as is also quinine, for thermic fever.

If the breathing stops, it is advisable to try artificial respiration for half an hour, as sometimes good results have ensued. If the heart begins to fail, hypodermics of strychnine or digitalin may be given. If convulsions are severe, inhalations of chloroform and oxygen mixed may be administered.

When the temperature is reduced, and the patient is conscious and can swallow, a dose of calomel (gr. iii. to v.), followed by saline purgatives, is advantageous. As soon as urine can be collected, it must be carefully examined for signs of renal trouble, which, if present, must be treated.

Bromides may be required to soothe the irritated nervous system, and do more good than hypnotics or morphine.

Food must at first consist of only milk with barley-water, or toast-water, and be given in small quantities and often; but as convalescence proceeds, broths, soups, eggs, milk-puddings, etc., can be added. No alcohol on any account must be given, except on the advent of collapse.

The room in which the patient is lying must be kept as cool as possible by punkahs, and large blocks of ice placed in baths, and it must also be kept dark—*i.e.*, well protected from the sun's rays, and also from the glare of electric light.

There is apt to be great intolerance of light and heat, and therefore, after thermic fever the patient should, if possible, go on leave to a cool climate.

Prophylaxis.—Prophylaxis consists in protecting the head and eyes from the sun, in wearing proper clothing, in living in dwellings and offices protected against the sun and kept as cool as possible, as described in the preceding chapter.

Muscular exertion should not be taken in the heat of a tropical day if it can be avoided, and during these hours alcohol should not be touched.

If any of the prodromata are noticed, the person should be put on the sick-list, and treated as though he were ill. He should be kept in a cool, shaded room; the bowels should be freely opened, and cool applications applied to the head. The diet should be light, without alcohol, and, when better, the patient should be extremely careful not to expose himself in any way.

HEAT SYNCOPE.

Synonyms.—Heat exhaustion, prostratio thermica.

Definition.—Heat exhaustion is a condition of syncope brought about by the action of high air temperatures, especially if associated with a considerable atmospheric humidity, upon persons whose bodily health or conditions are abnormal.

Climatology.—The climatology is the same as for thermic fever.

Ætiology.—Two distinct factors are necessary for the development of this condition:

1. High wet-bulb temperatures.
2. Abnormal bodily health or conditions.

The first factor has been sufficiently explained, but a word or two about the second is necessary. The second factor consists of any organic disease or chronic alcoholism, especially the latter, which is apt to cause fatty infiltration and degeneration of the heart wall, thus allowing dilatation of the organ under the stress of high air temperature.

This second factor also includes unsuitable clothing and too violent exercise, which under high wet-bulb temperatures are especially liable to induce syncope.

But alcohol is by far the most important predisposing cause, and accounts for the difference in mortality of expeditions in which soldiers are allowed to drink it, and those in which they are not.

Morbid Anatomy.—As was shown by Peiffer in 1851, the heart

There may be congestion of the brain, lungs, and other viscera, generally there is little to note.

Symptomatology.—The symptoms begin suddenly by the pers feeling very giddy, and sometimes sick and weak. If he attem to walk, he staggers, and may fall. He is pale, his pulse small a soft, his pupils dilate, and his skin is cold. The temperature subnormal, or there may be a transient initial rise, and there m be loss of consciousness, but this does not always take place. Th is often considerable pain in the head.

Generally the condition is quickly recovered from, sometin after a little sickness or fever, but at times it deepens into unc sciousness, and ends in coma and death.

Treatment.—When a person complains of feeling faint, lay h flat on his back in as cool a place as can be found, and loosen clothing. Dash a little water on his head, face, and chest, a give him a little brandy-and-water or sal volatile, if he can swallo but if he cannot, give a hypodermic injection of strychnine or ether and camphor. As soon as possible wrap the patient blankets, and apply hot bottles to various parts of the body.

Prophylaxis.—The prophylaxis is the same as for thermic fev Giles advises nux vomica to be administered before hard work the sun.

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SECTION B

CHEMICAL CAUSES OF DISEASE

CHAPTER VI

TROPICAL INTOXICATIONS

Classification of poisons—Poisons used criminally against man—Poisons taken accidentally by man—Poisons used criminally against cattle—Poisons used in trial by ordeal—Poisons used on weapons—Poisons used in fishing and hunting—Poisonous trades.

CLASSIFICATION OF POISONS.

The intoxications of the tropics are numerous, and it is only possible in this work to give a very brief glance at the more important.

These poisons may be classified according to their chemical nature, but this is perhaps not so convenient as to arrange them, according to the various purposes for which they are used, into—

1. Poisons used criminally against man.
2. Poisons taken accidentally by man.
3. Poisons used criminally against cattle.
4. Poisons used in trial by ordeal.
5. Poisons used on weapons.
6. Poisons used in fishing and hunting.
7. Poisonous trades.
8. Poisonous foods.

The first seven only will be treated in this chapter.

I. POISONS USED CRIMINALLY AGAINST MAN.

The poisons used criminally against man are very numerous, some of them being still but little known.

The medical practitioner should be on the alert to detect cases

It requires a highly and specially trained chemist, with a good laboratory, to detect some of the tropical vegetal poisons. Our experience indicates that highly trained public analysts with well-equipped laboratories, such as exist in Ceylon and some parts of India, are essentials in a tropical country; for they are useful, not merely for criminal investigations, which are very numerous when people's eyes are opened to the danger, but also for studying other problems.

Criminal poisoning, according to Waddell, is three or four times as frequent in India as in England, and nineteen times more prevalent in Calcutta than in England. With the general statement that poisoning in the tropics is common we agree, and further, we are of the opinion that it is more so in the East than in Africa, the reason being that in Africa only the fetish-man is able to present virulent poisons in an acceptable form, whereas persons with an elementary knowledge of poisons are common in the East. It is true that the drug mostly used for poisoning purposes is arsenic, and probably it alone in the East causes as many human criminal deaths as all the organic poisons put together; but these latter from time to time cause inquiries, and are by no means uncommon. The poisons used in different countries vary according to customs or traditions.

The poisons used against man may be divided into—A. Inorganic Poisons, and B. Organic Poisons.

A. Inorganic Poisons.

The most common inorganic poisons of the tropics are:

1. Arsenic in some form.
2. Perchloride of mercury.
3. Mineral acids.
4. Powdered glass (this is really a mechanical irritant).

Copper salts have been used for homicidal purposes, but this is unusual, though it is said to be fairly common in India, while accidental cases from using copper cooking-vessels were formerly not infrequent in the same country. Antimony is rarely used.

Powdered glass, though a mechanical and not a chemical irritant, calls for some remarks, as it is used in many parts of the tropics for homicidal and suicidal purposes, being an irritant poison. The injury caused is, of course, purely mechanical, and the more finely it is powdered, the less likely it is to cause serious injury, owing to mucus surrounding the particles. The glass is administered in food—*e.g.*, bread, spinach, sweetmeats, etc. The symptoms are those of irritant poisoning—retching, violent vomiting, spasms, convulsions, and racking pain. The most evident post-mortem feature is acute gastritis. The mucosa is covered with a layer of thick mucus, under which it is found to be hyperæmic and lacerated. In this mucus or on the mucosa the minute pieces of glass may be found. No other pathological signs need be present. The treatment is to administer any bulky food at hand, and then, if vomiting has ceased, to give an emetic, and finally a laxative.

B. Organic Poisons.

The poisonous plants of the tropics belong largely to the natural orders of the Apocynaceæ, the Loganiaceæ, Euphorbiaceæ, Liliaceæ, and Leguminosæ.

The following is a classification of the most important according to use and place:

1. **Poisons used for homicidal purposes.***

Aconitum. Several species	India and Ceylon.
Strychnos. Several species	
Gloriosa superba L.	
Cerbera thevetia L.	
Cerbera odollam Gärtn.	
Nerium odorum Soland.	
Jatropha curcas L.	
Paullinia pinnata L.	Brazil.
Thevetia ahovai D. C.	
Milletia seriacea W. :	Dutch Indies.
Barringtonia speciosa L.	Pacific Islands.
Cerbera lactaria Hamilt.	
Hyoscyamus falezlez Coss.	West Africa.
Oro of Sierra Leone (a cactus)	
Cleistanthus collina Benth.	
Melianthus major L.; M. comosus; M. minor; M. aregeana; Morea collina	South Africa.

2. **Poisons used for suicidal purposes.**

Opium, Papaver somniferum L.
Nerium odorum Sol.
Gloriosa superba L.

With this class there will be included poisons causing bodily harm.

3. **Poisons used for purposes of infanticide.**

Opium, Papaver somniferum L.
Calotropis procera R. Br.
Tobacco Nicotiana tabacum L., and other species.

4. **Poisons used for procuring abortion.**

A large number of poisons are used, some of which will be mentioned later.

5. **Poisons used to stupefy with intent to rob.**

Datura fastuosa L.

6. **Poisons used to simulate injuries.**

Plumbago rosea L.
Anacardium occidentale L.

CEYLON PLANTS.

By the kindness of Mr. Drieberg, we are able to give the following list of Ceylon plants known to be poisonous to men and cattle, but not commonly used against man.

1. Ammannia baccifera L.
2. Anamirta paniculata (A. cocculus) W. and A.
3. Arisæma curvatum Thw.
4. Chrozophora plicata A. Jacs.
5. Croton tiglium L.
6. Diospyros montana Roxb.
7. Elæodendron glaucum Pers.
8. Euphorbia tirucalli L.
9. Excœcaria agallocha L.
10. Datura fastuosa L.
11. Lagenaria vulgaris Ser.
12. Lasiosiphon eriocephalus Decne.
13. Lobelia nicotianæfolia Heyne.
14. Manihot utilissima Pohl.
15. Paspalum scrobiculatum L.
16. Plumbago zeylanica L.
17. Rauwolfia serpentina Benth.
18. Rhododendron arboreum Smith.
19. Ricinus communis L.
20. Sapium insigne.
21. Tylophora fasciculata Buch-Ham.
22. Withania somnifera Dun.

A few notes may, perhaps, with advantage be given on some of these poisons.

1. **Homicide.**—*Aconite.*—Aconite (Ranunculaceæ) is so poisonous that in India it is known as 'bish' or 'bikh,' which means 'the poison,' which generally refers to *Aconitum ferox Wall* (Himalayas), *A. napellus L.* (Himalayas), *A. luridume Aorte* (Sikkim), *A. lycoctonum L.* (Kashmir); whilst *A. heterophyllum Wall* and *A. palmatum Don.* are said to be less poisonous.

The root is the principal source of the poison, which, however, also exists in the leaves and stem.

Aconite is used for homicidal purposes, as a cattle poison, and may at times be taken accidentally. The fatal dose is said to be 30 grains of the root, and the fatal period usually three to six hours.

The symptoms are tingling of the lips, tongue, mouth, and fauces, followed by numbness and anæsthesia, burning pains in the stomach, and vomiting, muscular and cardiac weakness, and finally death takes place from failure of the heart or respiration.

The treatment is to empty the stomach by a stomach-pump or an emetic, followed by animal charcoal and stimulants. Hypodermically atropine and ether, with or without camphor, may be given.

Cleistanthus collina—*C. collina* (Euphorbiaceæ) has very rarely been used as a poison, though it has been mentioned in several books. When so used, it causes cramps in the limbs, purging, vomiting, and death in a day or so.

Cerbera odollam.—*C. odollam* (Apocynaceæ) is a very common plant in Ceylon, and is similar to *C. thevetia.* Its chemical properties have not yet been properly worked out, and it is said that it '*probably*' contains the same poisonous principle as C. thevetia—viz., thevetin. The symptoms are nearly the same—*i.e.*, gastro-intestinal irritation, followed by cardiac poisoning. These symptoms are easily mistaken for arsenical poisoning. The treatment is the same as for irritant poisoning in general.

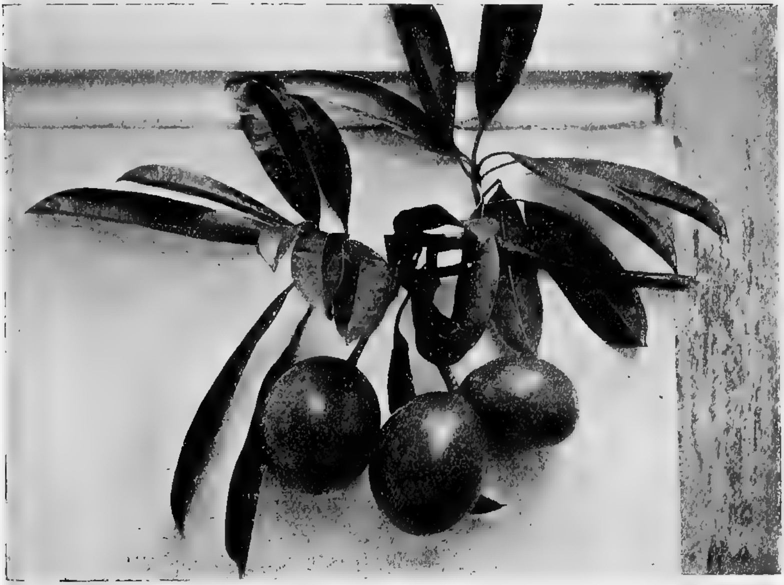

FIG. 14.—CERBERA ODOLLAM GÄRTN.

Cerbera thevetia. — *C. thevetia*, the common yellow oleander of India, is a shrub about 6 to 12 feet in height, with yellow, bell-shaped flowers and globular green fruit. It is highly poisonous, its action being due to a glucoside, thevetin, which exists in the milky juice pervading all parts of the plant. It is supposed that three seeds are sufficient to kill a man in twelve to fifteen hours, the symptoms being gastro-intestinal irritation, headache, dizziness, and pain in the throat. The pulse is very soft and slow—thirty to forty beats a minute—which Windsor says is characteristic; later it becomes weak, very rapid, and irregular. Death results from cardiac failure. The treatment is the same as for ordinary irritant poisoning.

Dendrocalamus strictus Nees.—According to Ridley, the fine hairs of bamboo sheaths are used in Malaya as a mechanical irritant. They are administered in food, and cause a severe form of enteritis.

Gloriosa superba.—*G. superba* (Liliaceæ) is a well-known poison in India and Ceylon, while in Burma it is said to be used for suicidal purposes. Its active principle, superbine, is said to be allied to, or identical with, the scillitin of squills, and therefore the action of *G. superba* is not unlike that of squills. The symptoms, which may appear in half an hour, are retching, violent vomiting, spasms, with contortions of the body and racking pains, with short intervals of relief from time to time. Death may take place in four hours. The post-mortem reveals congestion of the brain and membranes, with extravasations of blood; congestion of the lungs, liver, and kidneys; and inflammation of the mucous membrane of the stomach.

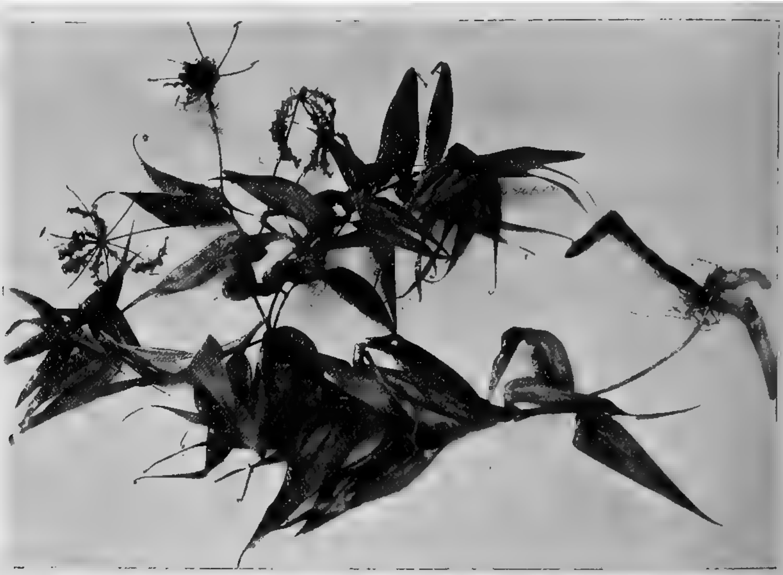

FIG. 15.—GLORIOSA SUPERBA L.

The treatment is that for irritant poisoning in general, and as already mentioned.

Hyoscyamus falezlez.—The Tuaregs are said to use *H. falezlez* to kill travellers.

Jatropha curcas.—*J. curcas*, the jura-tree of India, has a seed which is called the 'physic nut,' from which an oil can be expressed which is an irritant to the skin and a purgative.

The symptoms of poisoning are vomiting, purging, abdominal pain, derangements of the special senses, muscular twitchings, and loss of memory. The treatment, after getting rid of as much of the poison as possible, is lime-juice and stimulants.

Melianthus (Melianthaceæ).—Various species of Melianthus are said to be very poisonous by Grey, who suspects the possibility of their use by South African Bushmen.

Milletia seriacea (Leguminosæ) is a poison of the Dutch Indies, causing severe diarrhœa, collapse, and death.

Morea collina (Indaceæ).—*M. collina*, the wild tulip of South Africa, is said by Grey to have been used by a Bushwoman to poison a number of people, two of whom died.

The symptoms were severe vomiting and a feeling of constriction across the chest, feeble and intermitting heart, and a tendency to coma for hours before death. The post-mortem showed no rigor and no inflammation of the stomach. The heart musculature was flaccid, and the right side full of blood.

Nerium odorum.—*N. odorum* (Apocynaceæ) is the white oleander, and grows commonly in India, where it is a well-known poison. It is rarely used for homicidal purposes, but more generally for suicide, abortion, and accidental poisoning.

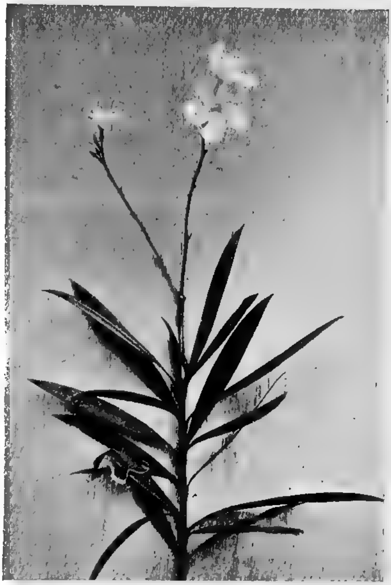

FIG. 16.—NERIUM ODORUM SOLAND.

The root is the portion used, but all parts are poisonous. The active principles are neriodorin, a powerful cardiac poison acting something like digitalis; karabin, a cardiac poison, with also a strychnine-like action on the spinal cord.

The symptoms are therefore (1) those of gastric irritation—viz., vomiting, pain in the stomach, frothing at the mouth from salivation, but, as a rule, without diarrhœa; (2) cardiac symptoms, producing at first a slow pulse, which finally becomes quick and weak—the respirations are rapid from the first; (3) strychnine-like symptoms of twitching of the muscles, tetanic spasms, with cramps and, at times, lockjaw.

Towards the end the patient becomes drowsy, then insensible, and finally dies from cardiac failure. The post-mortem reveals dilatation of the right side of the heart, which is full of blood, while the left side is empty, with subendocardial hæmorrhage, congestion of the liver, spleen, kidneys, and lungs, mucosa of the stomach and small intestine, while the large intestine and brain are normal. The patient must be treated on the same lines as for digitalis and strychnine poisoning.

The Oro.—The oro (a cactus) of Sierra Leone is a gastro-intestinal irritant, causing vomiting, diarrhœa, collapse, and death.

Paullinia pinnata (Sapondaceæ) is said by Rho to be used by negro slaves in Brazil to poison their masters, and to depend upon an alkaloid, timboin, for its action.

Strychnos.—Strychnos (Loganiaceæ) is a genus with several poisonous species, among which may be mentioned—

Strychnos nux vomica L.
Strychnos ignatii Berg.
Strychnos colubrina L.

Poisoning by the alkaloid strychnine is frequently met with in India, but is usually accidental. The symptoms of strychnine poisoning are bitter taste in the mouth, tetanic spasms, opisthotonus, risus sardonicus, and death from asphyxia or collapse. There are no characteristic post-mortem appearances, except congestion of the brain and spinal cord. The treatment is to empty the stomach by emetics, and to administer chloroform or chloral hydrate, and, when asphyxia threatens, to perform artificial respiration.

Thevetia ahovai.—*T. ahovai* is allied to the oleanders mentioned above, and has an alkaloid, thevetosin, said to cause gastric irritation and difficulty of breathing.

2. **Suicide and Bodily Harm.**—Of all the poisons used for suicidal purposes, opium is by far the most usual, though *Nerium odorum*, *Cerbera odollam*, and *Gloriosa superba* are also at times employed, the former especially by women in India. Rarer poisons are *Calotropis procera*, *Cerbera thevetia*, aconite, prussic acid, and veratrine (meeta bish). The action of all these poisons is described either in ordinary works on toxicology, or has already been mentioned.

Apart from actual suicide, certain drugs have a distinctly deleterious effect upon human beings when taken for long periods, and those in use in the tropics are alcohol, opium, cocaine, Indian hemp, and many others. The effects of alcohol are sufficiently dealt with in books on ordinary medicine, and need not be described here.*

Opium is eaten in Persia, India, and Africa, and smoked in Malay, Indo-China, and China, but for the latter process it has to be specially prepared. On the Eastern mind opium is said to have two possible effects: either it produces a sense of absolute blank, or it produces fancy dreams and visions. The effects of chronic morphinism are loss of appetite, emaciation, and exhaustion, and hence inability to think or work.

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* Alcoholism, which is on the increase, may be caused by indigenous forms of stimulants, such as arrack, or, more dangerously, by imported cheap whiskies, gins, and rums, which greatly deteriorate native races.

It is, however, probable that the effects of opium are not as bad as those of alcohol, and, used in moderation, may not be more harmful than the use of tobacco.

Cocaine has been used much of late in India as an intoxicant or stimulant to counteract the effects of opium. Unfortunately, children have begun to habitually use the drug. The cocaine is chewed with betel and chunam (slaked lime), and produces at first loss of sensation in the tongue and lips, followed by dryness of the mouth and fauces. The temperature does not rise, but the pulse becomes full and quick, and at this stage the inebriate likes to be left alone, and firmly closes his lips lest the saliva should flow out. His ears become hot and red, his cheeks pale, and the tip of his nose cold. Perspiration breaks out, and the maximum amount of the so-called hilarity or exaltation, due to over-stimulation of the nervous system, now appears, but is speedily followed by depression, which induces the victim to take another dose. The teeth and tongue of the confirmed cocaine-eater turn jet-black, probably due to some chemical change produced by the action of lime and saliva on cocaine. Pernicious symptoms in the form of emaciation accompanied by insomnia, digestive disturbance, diarrhœa, deafness, diminution of urine, delusions and hallucinations, and even at times acute mania, may appear.

Indian hemp (*Cannabis sativa*) is used in India, Arabia, Persia, and elsewhere as a narcotic. It must be remembered that *C. sativa* grown in India has quite different properties from the same plant grown in Europe. In India there are four varieties sold: bhang, consisting of the dried leaves and stalks reduced to a powder; ganja, the flowering tops; charas, the resin from the leaves; and majun, a sweetmeat prepared with hemp. In Central Asia the resin is called haschisch.

Its action on man is first to produce a pleasurable excitement, and later narcotism. In moderate doses it temporarily increases the feeling of strength and power. As an intoxicant it is much used, being eaten or smoked, and is said to be one potent cause of insanity in India. Waddell says that about 38·4 per cent. of Bengal lunacy can be traced to this source. It is asserted to be one of the causes of the strange phenomenon called 'running amok,' but this will be dealt with in detail later on, under diseases of the Nervous System.

Kawa is an intoxicating drink prepared from the root of *Piper methysticum Forst.* (Piperaceæ), which grows throughout Polynesia.

According to Lewin, kawa contains starch, flour, two inactive substances—kawain and yangonin—and 2 per cent. of resin, which is believed to be the active principle. But this resin, by treatment with symptoms of inco-ordination and headache, and a desire for sleep, and may induce liver disease, dermatitis, and general debility. Taken in moderation, it is said to be harmless.

Peyottl (pellote) is a narcotic used in Mexico, and derived from the cactus *Anhalonium lewinii Henn.* It causes sleep with hallucinations.

Species of Coriaria—C. ruscifolia L., the poison-foot of New Zealand, and *C. myrtifolia L.* (a native of Europe)—are considered to be intoxicant or poisonous, according to the dose. The symptoms are coma, convulsions, and dilated pupils. From *C. ruscifolia* the Maoris are said to prepare a wine and jelly.

Other Poisons.—In Malacca the leaves of *Mitragyna speciosa Korth* (Rubiaceæ) are said to be used in place of opium. From the leaves of *Bassia latifolia Roxb.* and *B. longifolia L.* (Sapotaceæ) intoxicating drinks are made. *Anacardium occidentale* (the marking nut tree) is sometimes used to torture or disfigure people. *Hyoscyamus muticus* is used as an intoxicant by the Baluches, and makes them dance like lunatics.

3. **Infanticide.**—Infanticide exists in the tropics in two forms—the first irrespective of sex, and said to be due in India (Waddell) to the high-caste Hindu prohibiting remarriage of widows ; and, secondly, female infanticides, to prevent too many daughters growing up. A few of the more commonly used drugs may be briefly mentioned.

Opium is used in India by smearing the mother's nipples with the drug. There is little necessity here to describe the action of opium. All that need be said is to warn the practitioner that ayahs (native nurses) are apt to soothe a baby to sleep by dipping the finger in laudanum, and giving it to the baby to suck. Such treatment is highly deleterious to the child, and the intensely contracted pupils should make the practitioner suspect its use in an obscure case of illness.

Calotropis gigantea R. Br. and *C. procera R. Br.* (Asclepiadeæ), called 'mador' in Hindustani and 'erukam' in Tamil, have been used in India for infanticide and abortion, rarely for suicide, and more rarely for homicide. The symptoms are vomiting, profuse salivation, severe tetanic spasms, extremely slow and stertorous breathing, and dilatation of the pupils. The active principle is a yellow, bitter resin, but there is no alkaloid. The treatment is the same as for irritant poisoning.

Tobacco is also used as an infant poison.

4. **Abortion.**—Criminal abortion is very common in the tropics. In India it is said to be common among Hindu widows, because they are not allowed to remarry.

The drugs commonly used are :

(1) *Reputed Emmenagogues :*

Nerium odorum Sol.
Cerbera thevetia L.
Carica papaya L. seeds.
Daucus carota L. (the carrot) seeds.

(2) *Purgatives—Curcurbitaceæ :*

Cucumis trigonus Roxb.
Momordica charanta L.
Momordica cymbalaria Fenzl.

(3) *Irritants.*—Several inorganic irritants are used—arsenic, lead, mercury, copper, quicklime.

Plumbago rosea L.
Plumbago zeylanica L.
Calotropis procera R. Br.
Piper nigrum L. (black pepper).
Unripe pine-apple.
Moringa pterygosperma Gärtn. (bark).
Lasiosiphon speciosus Decne.

(4) *Supposed Ecbolics :*

Juice of bamboo-leaves (Bambusa sp ?).
Fruit of *Randia dumetorum L.*
Decoctum of *Cuscuta reflexa Roxb.* (this is also an irritant).
Seeds of *Celastrus paniculatus W.*
Seeds of *Anethum graveolens L.*

Plumbago zeylanica and *P. rosea* are evergreen shrubs about 2 to 5 feet high, in the root of which there is an active principle, plumbagin, which acts externally as a vesicant, and internally as an irritant and narcotic. It is used as a paste or spread on wool on an abortion stick.

The abortifacients commonly used in Ceylon are *Gloriosa superba*, violent purgatives (including large doses of magnesium sulphate), and the twigs of the castor-oil plant, the last named being a mechanical irritant.

5. **Stupefying with Intent to Rob.**—Two drugs are much used in India and Ceylon for the purpose of stupefying with intent to rob—viz., *Datura fastuosa* and *Cannabis sativa.*

Datura fastuosa (*Solanaceæ*).—Poisoning by datura is common in India, having been used by the Thugs. The seeds are usually mixed with food or drink, and the symptoms, which develop rapidly, depend upon the dose, being generally those of a cerebral poison. First there is delirium, and later coma, but in both conditions the pupils are widely dilated. The delirium is peculiar ; for example, the people affected may be found searching their bedding most vigorously for some lost article. When death occurs, it is due to cardiac failure. The fatal dose is not accurately known, but may be about 10 to 15 grains of the seeds. Waddell puts the mortality at about 18½ per cent. The post-mortem characteristics are wide morphia, and pilocarpine nitrate in ¼ to ½ grain doses, as advised by Ringer.

The action and effects of *Cannabis sativa* have already been described.

6. **Used to simulate Injuries.**—*Plumbago rosea* and *Anacardium occidentale* are used to simulate bruises and other injuries in order to get innocent people into trouble.

II. POISONS TAKEN ACCIDENTALLY BY MAN.

Accidental poisoning happens fairly frequently; therefore a few examples may be given.

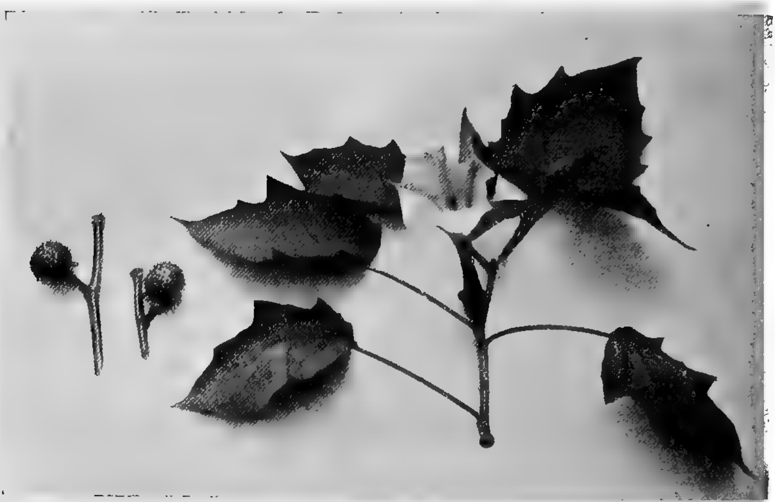

FIG. 17.—DATURA FASTUOSA.

Certain common articles of food are poisonous until properly prepared; *e.g.*, tapioca is the starch obtained from the root of *Manihot utilissima* Pohl (*Jatropha manihot* L.), commonly called the cassava, of which there are two varieties—the sweet and the bitter. The latter contains hydrocyanic acid in its milky juice, and is therefore poisonous until it is roasted, when the volatile acid is driven off, and the bitter cassava can then be used for food after squeezing out the juice and cooking the root. Waddell reports two cases of death from accidental poisoning by this root in 1898 in Madras.

Capsicums (*C. annuum* L.), if taken in large quantities, may cause burning in the mouth and throat, vomiting, colic, diarrhœa, and even death.

Lewin states that *cinnamon-bark* (*C. zeylanicum* Nees) may be poisonous, while *nutmegs* (*Myristica fragrans* Houtt.) are well known to be poisonous if taken in large doses.

Vanillismus is poisoning by the dried fruit of *Vanilla planifolia* (Andrews), which causes colic, vomiting, and pains in the head and muscles. Men working with it may suffer from conjunctivitis, fits of sneezing, and a skin eruption called vanilla itch, characterized by swelling, followed in a few days by scaling, may develop. There is, however, great doubt as to what is the real cause of these symptoms. Probably it is due to some impurity in the vanilla.

Chailletia toxicaria Don. (Chailletiaceæ) (native name, magberi or manuch), the powdered fruit of which is used for killing rats, has been described by Renner, in Sierra Leone, as the cause of poisoning in a Mendi carrier.

The symptoms were mainly vomiting, diarrhœa, trembling, general weakness, and inability to walk because the legs were paralyzed, the tendon reflexes having disappeared. Hyperæsthesia was present over the inner side of the thighs and legs, and pressure on the calf muscle gave severe pain. The bladder, rectum, and pupils were normal. The man recovered in about two months.

Renner remarks that this case is probably the clue to attacks of sudden paralysis of the lower limbs in young persons (twenty to forty years) of both sexes in Sierra Leone. When death ensues, it is from paralysis of the muscles of respiration.

The seeds of Ricinus communis L. (Euphorbiaceæ), the castor-oil plant, are poisonous, causing burning in the throat and abdomen, vomiting, purging (may be absent), and collapse. The fatal dose appears to be three seeds, and to kill in about forty-six hours. Post mortem, the principal feature is gastro-intestinal inflammation.

The treatment is emetics, stimulants, and hypodermics of morphia.

The fruit of Hippomane mancinella L. (Euphorbiaceæ), the manchineel-tree, of the Grenadine Islands, which has a delicious fragrance, is said to have been the cause of many sailors meeting their deaths, for it looks like an apple. The active principle is not known.

The symptoms are severe pain in the mouth and stomach, followed by collapse. The lips and tongue become swollen and blistered, the abdomen tender, the pupils widely dilated, while bullæ appear on the skin.

The treatment consists of stimulants and hypodermics of ether, with mouth-washes. Internally opium, bromides, chlorate of potash, bicarbonate of soda, or bismuth, made into an emulsion, may be given.

III. CATTLE-POISONING.

Cattle-poisoning is a frequent method of revenge in India.

The following list, taken from Waddell's work, indicates the drugs and methods in use, together with their relative frequency :

Arsenious oxide	696
,, ,, with sulphite	9
,, ,, with oxides of lead	9
Sulphides of arsenic only	11
Oxides of lead only	6
Sulphate of copper	6
Nux vomica	1
Cocculus indicus	3
Mercury	1
Sulphate of iron	1
	743

But, in addition, *Abrus precatorius* L., *Cerbera thevetia* L., *Calotropis procera* R. Br., aconite, chopped hair, and snake-venom have been used. The list of Ceylon plants poisonous to man and cattle has already been given. It is important to remember that rinderpest and dysentery resemble arsenical poisoning, while poisoning with nux vomica may resemble tetanus.

Grey says that *Lessertia annularis*, the t'neuta of the Karroo of South Africa, produces cerebro-spinal paralysis in sheep and goats, like *Gastrolobium*, the poison-pea of Australia. Only *Abrus precatorius* need be discussed here.

Abrus Precatorius (Leguminosæ).

The juice of this plant is most irritating, and, if injected under the skin of cattle, proves rapidly fatal, by producing general depression, drowsiness, fall of temperature, and hæmorrhagic lesions somewhat like those of snake-venom.

The decorticated seeds are made into a paste, which is worked into sharp-pointed little needles, and hardened in the sun. Two of these are inserted by their bases into a wooden handle, and then driven with great force into the animal's flesh.

The active principle is abrin, a tox-albumin resembling snake-venom, which causes thrombosis and death in from eighteen to twenty-four hours.

IV. POISONS USED IN TRIAL BY ORDEAL.

Curious customs exist in savage lands of trial by ordeal, in which the patient is given a drug and then ordered to perform some act. Waddell records the history of an old Hindu woman who was supposed to be a witch. She was tried by ordeal, being given a poisonous drug (datura) in treacle, as it is a native belief that a witch can withstand poison. The result of the ordeal was that the poor woman died.

Rho gives an account of trial in West Africa by 'imbundi,' the sliced root-bark of *Strychnos icaja* (Baill), which is said to contain strychnine. The accused, after drinking a concoction of the root, is made to jump over a stick, and is pronounced guilty unless he is able to do this, or to pass urine on to a banana-leaf, both of which feats are usually impossible.

Christison mentions the Calabar bean of West Africa, *Physostigma venenosum* Balf. (leguminosæ), as being used in trial by ordeal, the belief being that the innocent vomit and are safe, while the guilty retain the poison and die. Its antidote is atropine, administered hypodermically.

Erythrophlæum judiciale Proct., *Tanghinia venenifera* Poir., which contains a toxic base with an action like digitalin, and *Menabea venenata* Baill are used in Madagascar, and *Adenium somalense* Poir in Somaliland, for purposes of trial by ordeal.

V. POISONS USED ON WEAPONS.

Arrow-Poisons.

The arrows of primitive peoples produce wounds which are by no means usually fatal, and therefore, in attacking big game or in warfare, it is obvious that some poison which will insure the death of the victim fairly quickly will be valuable.

Usually these poisons, or the more potent of them, are only known to the fetish priests or chiefs, and are generally mixed with all sorts of animal extracts, the whole being made into a paste, and painted on the arrow-heads.

If a special poison is prepared, as a rule some sort of precaution is also taken, so that the owner of the arrow may not be accidentally wounded. Thus, the Fra-Fra people, when preparing against the invasion of their country, obtained a very potent poison, which, however, they handled with great caution, though they boasted that they had an antidote. They kept these arrows, as a rule, in special quivers, and each arrow had a tiny stick tied to its shaft, so that it could be carefully lifted out of the quiver. Moreover, a tuft of red material was tied to the base of each of these sticks, so that there could be no mistake as to which were the specially poisoned arrows.

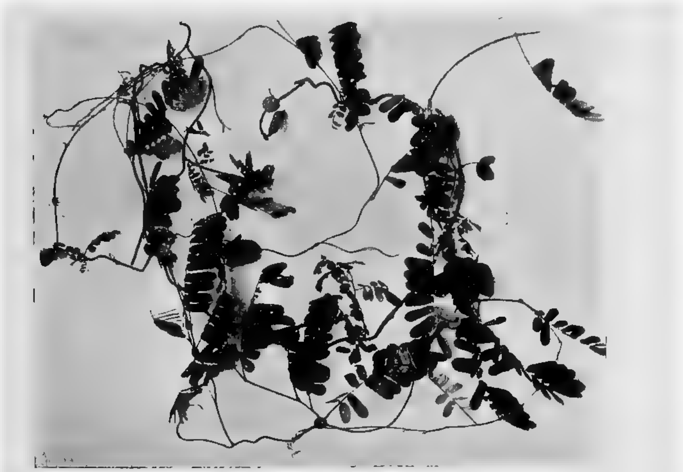

FIG. 18.—ABRUS PRECATORIUS L.

Arrow poisons may be classified into those of animal origin and those of vegetal origin. The most common animal arrow-poisons are snake-venom, scorpions, spiders, and beetles, crushed and mixed with vegetal poisons. The Bushmen of South Africa and the natives of Togoland make an arrow-poison by burning and powdering the heads of adders and vipers, regardless of the fact that the burning must destroy the venom. The Bushmen of the Kalahari Desert make a poison from the larvæ of *Diamphidia simplex* Paringuey, which is thought to be really a toxin due to some micro-organism growing in the decomposing larva. But animal poisons are not nearly so common as vegetal poisons.

The most important natural orders containing vegetal arrow-poisons are, firstly, the Apocynaceæ, which contains the genera Acocanthera, Strophanthus, and Adenium, all of which are common African poisons; secondly, the Loganiaceæ, with the genus Strychnos, which is of great importance in Asian poisons; thirdly, the Urticaceæ, with the important ipoh poison of Sumatra, Borneo, and Indo-China; and fourthly, the less important orders of the Ranunculaceæ, containing *Aconitum ferox* (Wall), used in India, the Leguminosæ, and the Euphorbiaceæ, containing some African poisons.

The actions of arrow-poisons are very varied, and may be classified into—

1. An action on the heart and muscles like that of digitalis.
2. An action on the peripheral nerve-endings like that of curari.
3. An action on the nervous system and heart like that of aconite.
4. An action on the nervous system like that of strychnine.
5. An action resembling snake-venoms.

The general treatment of a poisoned arrow wound is as follows:

1. *Tie a tight band on the heart side of the wound*, if on a limb, to prevent absorption of the poison.

2. *Remove the arrow as quickly as possible.*

The difficulty in withdrawing the arrow-head is the presence of barbs, which can be prevented from doing mischief by thrusting the head through the skin on the far side of the limb—there is no necessity to fear about the bloodvessels, for they will slip away from the arrow—then cutting the shaft off, and drawing the head through on the far side, and the shaft on the near. If it is in the body, a good plan is to enlarge the wound and pass down some sort of a cannula—*e.g.*, a hollow bamboo—over the head, and then withdraw the whole arrow.

3. *Wash the wound with permanganate of potash.*

Having withdrawn the arrow, wash the wound out thoroughly with a 3 per cent. solution of permanganate of potash (if this cannot be done, cup the wound or suck it), in order to neutralize any snake-venom, and, indeed, any other poison capable of being oxidized.

4. *Keep the heart working.*

Give stimulants—*e.g.*, hypodermics of strychnine—after the arrow is removed and the wound washed.

5. *After-treatment.*

Treat the hurt as a poisoned wound. A dose of antitetanic serum would be good, if available.

Some of the principal arrow-poisons require to be described in more detail.

1. **African Arrow-Poisons.**—The natural order Apocynaceæ contains, as already stated, several genera of plants which provide celebrated arrow-poisons much used by native peoples in Africa.

These genera are Acocanthera, Strophanthus, and Adenium.

Acocanthera Arrow-Poison.—The genus Acocanthera supplies the most important arrow-poisons of East, Central, West, and South Africa. The poison, which is called waba, wabajo, or ouabaio, was first fully described by Burton in 1856. It is prepared from the tree *A. schimperi* (Dĕc) in Abyssinia and throughout the greater part of East Africa, being used by the Wataita, the Wakamba, and probably other tribes. The special Fra-Fra arrow-poison of the Gold Coast is probably derived from some species of Acocanthera. In Erythræa and Yemen *A. deflersii* Schweinfurth is used, and in Somaliland *A. ouabaio* Cathelineau. These trees are 4 to 5 metres in height, with dark green foliage, white or red flowers, and violet-red fruit. The poison is usually prepared by making a decoction of the wood, and evaporating it down until it becomes a thick tar-like extract, which contains the active principle. This principle, which is a glucoside called ouabain, acocantherin, or wabain, is a powerful cardiac poison. In addition, the natives generally add snakes' heads and gall-bladders to the tar-like mass; but it is doubtful whether these really increase its virulence, though it must be admitted that sometimes there are symptoms analogous to snake-poisoning.

The thick extract of the wood containing any other additions, which individual peculiarity may consider necessary, is now painted upon the arrow-heads.

The action of the freshly prepared poison is very rapid, death taking place in a few minutes through stoppage of the heart, after a preliminary quickening of the respirations and convulsions. Sometimes pain is complained of in the lumbar region. The symptoms can be readily prevented by a 3 per cent. solution of permanganate of potassium. The native remedy is believed to consist in eating some of the poison.

Another important Acocanthera poison is *A. venenata* Thunberg, which is employed by the South African Bushmen, and is said to be made from a decoction of the bark. The symptoms are rigors, without convulsions, and loss of muscular power, followed by death in a few minutes.

Strophanthus Arrow-Poison.—Livingstone was probably the first to draw attention to a Strophanthus arrow-poison called kŏmbi, used in Central Africa. *Strophanthus hispidus* D. C. is a very cŏmmon plant in many parts of West and Central Africa, and is a common arrow-poison, but not nearly so deadly as that of Acocanthera. The other varieties used are *S. glabris*, *S. kambe*, *S. lanosus*, *S. ciabé*, *S. barika*.

The poison is obtained by cooking the seeds in water, and adding snakes' heads and leaves and roots of other plants. The injured man falls to the ground, and his breathing and pulse become gradually slower and slower, until the heart-beats suddenly cease, and death ensues, preceded by a convulsion in about ten to fifteen minutes. The heart stops in systole, and will not contract on stimulation. Strophanthus is used on the Congo, Lake Nyassa, Zambesi, Gaboon, Guinea Coast, Gold Coast, Cameroons, and Senegambia as an arrow-poison.

Adenium Arrow-Poison.—There are two species of Adenium used in Africa—viz., *A. boehmianum* Schinz and *A. somalense* Oliver.

A. boehmianum, which is a shrub about 1½ to 2 metres in height, is used by the Ovambo of German South-West Africa to prepare an arrow-poison called echuja. The thickest branches or roots are cut across and held over a fire, when the thick, viscid sap exudes in threads, and is collected by winding it round small pieces of wood. The arrow-heads are now moistened by spitting upon them, and then smeared with the sap.

The active principle is echujin, which is a very virulent cardiac poison. The Somaliland species is equally virulent.

Erythrophlœum judiciale Proct.—Its active principle is an alkaloid, erythrophloem, which causes dyspnœa, first slowing and then quickening of the heart, and finally death from stoppage of breathing. It is used by the Pigmies of Central Africa; but the principal Pigmy arrow-poison is a mixture of this with strychnine, which will kill an elephant. Prompt treatment, however, is said to be able to save a man's life when wounded by one of these arrows.

Munchi Arrow-Poison.—The Munchi arrow-poison, which is used by the Backorana clan in Northern Nyeni, is said to be nearly always fatal to man in about half an hour. The method of preparation is not known, but the poison is plastered in a thick layer on the long point of the barb. It is of a brittle, dark brown colour, with slightly aromatic odour, and is insoluble in cold or warm water, in normal saline or acidulated solution, but dissolves easily in alkalis—*e.g.*, 1 per cent. Na_2CO_3 solution. It has no alkaloidal properties, and does not reduce copper sulphate in alkaline solution. No fluorescence occurs with H_2SO_4, and there is only slight reducing power after prolonged boiling with mixed acids. It acts by paralyzing the heart and the striated skeletal muscles, but no distinct action on the muscle plasm can be detected. The toxic substance is thought to belong to the class of resinous acids.

Euphorbia candelabrum.—This is supposed to be one of the ingredients of the poison '*uciunga*' (meaning poison), used by the Wafiomi, Wagogo, of German East Africa. The other ingredients are not known. According to Brieger, the active principle is exactly the same as in Acocanthera. Rho says the Wakamba use a similar poison.

Less important African arrow-poisons are :—

(a) *Used by the Monbattu Dwarfs*—

1. Erythrophlœum guineense G. Don., belonging to the Leguminosæ of which the bark is used.
2. Palisota barteri Benth.
3. Combretum grandiflorum.
4. Strychnos icaja Baill.

(b) *Used by the Hottentots and South African Bushmen*—

5. Hæmanthus toxicaria (L.).
6. Euphorbia cereïformis L.
7. Euphorbia virosa W.
8. Euphorbia heptagona L.
9. Euphorbia arborescens.
10. Hyænanche globosa.

2. **Asian Arrow-Poisons.**—The best known of these poisons ar those used in Malaya, Sumatra, and Borneo, and prepared fro the following :

Urticaceæ—

(1) Antiaris toxicaria Lesch.

Leguminosæ—

(2) Derris elliptica Benth.

Loganiaceæ—

(3) Strychnos tieuté Lesch.
(4) Strychnos wallichiana Benth.
(5) Strychnos maingayi Clarke.

Rubiaceæ—

(6) Lasianthus flavescens Korth.

Dioscoreaceæ—

(7) Dioscorea hirsuta Bl.

Aroideæ—

(8) Amorphophallus campanulatus Blum.

Apocynaceæ—

(9) Tabernæmontana malaccensis Hook.

Antiaris toxicaria.—*A. toxicaria* (Lesch) is a tree growing i Malaya, the sap of which provides the arrow-poison known as ipuh ipo, ipoh, ternek, kyass, poön upas, etc. It is used by the Sakai of Malacca, the Battaks of Sumatra, the Dyaks of Borneo, and th Mois of Cochin China.

Brandwood's dart-poison, dajaksch, from Borneo, appears to b from the juice of *A. toxicaria.*

The earlier travellers in Malaya gave wonderful accounts of th upas-tree and its action, which were purely imaginary. Delisl and Magendie appear to have been the first to make experiment with the poison in 1810, and they were followed by Brodie in 1811 who showed that the heart-beats became weak and irregular before respiration or the mental faculties were impaired.

There appears to have arisen a confusion between the juice of *A. toxicaria* and *Strychnos tieuté*, which explains the finding by Hedbon and Welting of strychnine in upas antiar. Pelletier and Caventou, the discoverers of quinine, studied the chemistry of the poison, and in 1838 Mulder isolated the active principle as a crystalline body, which he called antiarin, which in 1868 Deirij and Ludwig showed to be a glucoside.

Kiliani in 1896 investigated antiarin, and found its formula to be $C_{27}H_{42}O_{10}$. The physiological action of the poison has been investigated by a large number of observers, notably by Hedbon, Kiliani, and Seligmann, the last-named observer giving a most excellent account of ipoh as used by the Kenyahs of the Baram district of Sarawak.

The poison is prepared from the inspissated juice of the tree, and is either used alone or is mixed with *S. tieuté*, snakes' heads, or other substances. The whole concoction is made into a paste with water, and applied to the heads of the arrows, which are then dried before a slow fire.

The poison acts on the ventricles of the heart, behaving like digitalis, and, in addition, causes paralysis of the cerebral nervous system and passing clonic spasms of the voluntary muscles.

The Strychnos Arrow-Poisons.—Strychnos tieuté Lesch is the upas tieuté of Borneo, *S. wallichiana* Benth is the ipoh aker, and *S. maingayi* the aker lampong of the natives of Malacca.

The poisons obtained from these plants are said to contain strychnine and curari. The symptoms are said to be paralysis of the muscles, abolition of the reflexes, and stoppage of the heart and respiration. The urine contains a substance which reduces Fehling's solution.

Aconite as an Arrow-Poison.—Aconitum ferox Wall, belonging to the natural order of the Ranunculaceæ, is used by the Himalayan tribes from Assam to Kashmir as an arrow-poison, and several Sepoys have been mortally wounded in expeditions.

The poison is applied as a paste to the arrow, and is said to be mixed with septic blood to increase its effects (Waddell). It is also said to be used along the French and Chinese frontiers of the Indian Empire, and by the Amos in Japan, but the latter are believed to mix it with tobacco.

Less important Asian arrow-poisons are:—*Guatteria veneficum* Mart, *Cocculus toxiferus* Mart, *C. amazonum* Mart, which are also used in India as arrow-poisons, the active principle being curari.

Arrow-Poisons of the Philippine Islands.—The arrow-poisons used by the Negritos of the Philippine Islands are *Rabelaisia philippinensis* Planch, which causes paralysis of the extremities, dyspnœa, convulsions, and cessation of the heart's action.

Australasian Arrow-Poisons.—Le Dantec, quoted by Vaughan and Novy, says that the poisonous arrows of the natives of the

New Hebrides are prepared by smearing the points, which a usually made from human bones, with, first, a vegetable resin, ar then with slime taken from marshy places.

American Arrow-Poisons. — The important American arro poisons used in the valleys of the Amazon and Orinoco belong the Loganiaceæ, and are *Strychnos toxifera* Schomb, *S. crevaux* Planch, *S. castelniæana* Weid.

The active principle is curari, and, it is said, curin. Curari, ourari, was first brought to Europe by Sir Walter Raleigh in 159 The drug paralyzes the motor end-plates, and causes death fro failure of the respiration.

Less important American arrow-poisons are :—

(*a*) Paullinia pinnata (L.), used by native Indians of Brazil.
(*b*) Piscidia erythrina (L.), used in Brazil and Central America.

VI. POISONS USED IN FISHING AND HUNTING.

(*a*) **Fish Poisons.**

It is a common practice all over the world to throw pieces of bark or leav of trees and shrubs on to the water, in order to stupefy fish, and thus enab them to be easily caught.

The number of plants used for this purpose is very great, and though v have not thought it necessary to give a detailed list in this book, still, we co sider that it is useful to give a few examples, as a knowledge of the subject at times required.

The plants used in Ceylon for the purpose of intoxicating or killing fish a given in the following list, kindly supplied to us by Mr. Drieberg :

1. Anamirta paniculata (A. cocculus W. and A.).
2. Barringtonia acutangula Gärtn.
3. Euphorbia tirucalli L.
4. Lasiosiphon eriocephalus Decne.
5. Maesa indica Wall.
6. Mundulea suberosa Benth.
7. Randia dumetorum Lamk.
8. Strychnos nux vomica L.
9. Walsura piscidia Roxb.
10. Derris uliginosa Benth.

Hydnocarpus venenata Gärtn. is also said to be used, and to be poisono on account of the hydrocyanic acid it contains.

In India the following are used :

Anamirta cocculus Wight (Menispermaceæ).
Dolichandrone falcata Seem (Bignoniaceæ).

In Java and Sumatra :

Pittosporum densiflorum Puttal (Pittosporeæ).
Tephrosia toxicaria Pers.
Tephrosia piscatoria Pers.

In the Phllippine Islands :

Sapindus rarak D. C. } Sapindaceæ.
Harpulia arborea Radlk }

In the Dutch East Indies :

Derris elliptica Benth (Leguminosæ).
Pachyrhizus angulatus Rich.

Both of these plants contain a non-nitrogenous substance, called respectively derrid and pachyrrhizid, highly poisonous to fish. Derris-root will kill fish in a dilution of 1 to 25,000 of water, and derrid in 1 to 5,000,000.

In the West Indies :

Piscidia erythrina L.

This plant, called the Jamaica dogwood, is used by throwing the leaves and entire branches into the water, when the active principle, piscidin, dissolves out and paralyzes the fish, which are easily caught floating on the surface.

(*b*) **Mammalian Poisons.**

In India the root of *Arum montanum* Roxb is said to be used to poison tigers, while aconite is employed for the same purpose against elephants.

Many rat-poisons are known, especially *Tylophora fasciculata* Buch-Ham (Asclepiadeæ), *Chailletia toxicaria* Don (Dichapetalaceæ), both of which are used in Africa, and *Dianella nemorosa* L. (Liliaceæ) in Malacca.

VII. POISONS USED IN TRADE.

In the natural order of the Anacardiaceæ there is the genus Rhus, some of the species of which are well known to cause a dermatitis.

Thus, *Rhus venenata*, the poison-ivy of the Western States of America, has many times been recorded as the cause of this disease. Other species known to cause dermatitis are *R. toxicodendron*, *R. lobata*, and *R. pumila ;* but for the present purpose only *R. vernicifera* is of importance.

Lacquer Poisoning.

Lacquer is obtained from a brown treacle-like balsam, which exudes when incisions are made into the lacquer-tree, *Rhus vernicifera* Candolle.

The disease is acquired in two ways : either by direct contact with the lacquer, or through the fumes arising from it by evaporation, but only as long as the lacquer is not dry, for the poison, whatever it is, disappears on drying.

The symptoms, which develop in a few hours, are fever, with tension and œdema of the skin of the face, limbs, and generative organs, nasal and conjunctival catarrh, while a papular eruption appears on the œdematous skin of the legs and forearms.

The treatment consists in washing the skin thoroughly with soap and water, and applying soothing applications, such as cold lotions, or lotio plumbi subacetatis.

As prophylaxis the Chinese rub the hands and face with rapeseed oil in which a ham has been boiled, and wear a linen mask for the face and a leather apron for the body. After work the exposed parts are rubbed with a decoction of chestnuts, pine-bark, saltpetre, and amaranth.

The above precautions are taken in China, but in Japan no such prophylaxis exists.

Jatropha Poisoning.

While on the subject of irritating plants it may be mentioned that *Jatrop* *areus* of the West Indies has leaves covered with stinging hairs, which a said to cause extreme collapse, followed by pain and swelling of the affect parts when touched.

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CHAPTER VII

TROPICAL INTOXICATIONS (*continued*)—POISONOUS FOODS

Bromatoxismus—Zootrophotoxismus—Fuguismus—Sitotoxismus—Lathyrismus—Loliismus—Paspalismus—Atriplicismus.

VIII. POISONOUS FOODS.

Food poisoning, technically called bromatoxismus, may be divided into two classes :

1. Animal food poisoning.
2. Vegetal food poisoning.

1. ANIMAL FOOD POISONING.

Animal food poisoning is called zootrophotoxismus, and may be due to—

(*a*) Products normally present in certain animals, but poisonous to man.

(*b*) Poisonous food having been eaten by an animal prior to its being killed for food.

(*c*) Products abnormally produced in the living animal.

(*d*) Post-mortem decomposition.

But of these we need only concern ourselves with the first and the last.

Products normally Present in the Animal.

Poisoning by products normally present in the animal is called 'siguatera,' and is generally due to fish.

The most dangerous fish are those living among coral reefs, and particularly those which are bright-coloured. It is possible that the poisonous properties may be due not so much to the fish itself as to the fact that it has eaten decomposing food, such as dead medusæ, corals, etc.

Certain species of the genus Clupea (Cuvier), particularly *C. thrissa* (Osbeck) are noted as being very poisonous, but there is considerable doubt about this matter, as no scientific work has been done on the subject. The symptoms are gastro-intestinal irritation, which may lead to collapse and death. Another fish which is only poisonous at certain seasons is a so-called sardine *Clupea longiceps* (*Sardinella neohowii Val*), found off the coasts of Ceylon, and which, according to Tennent, caused much sickness years ago.

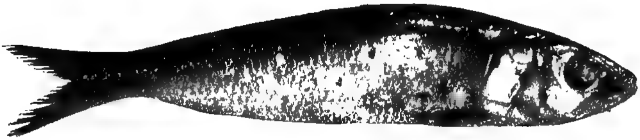

FIG. 19.—CLUPEA LONGICEPS (SARDINELLA NEOHOWII).

Other poisonous fish are *Tetrodon hispidus*, the 'muki-muki' or death-fish of Hawaii, and the file fishes, of which *Stephanolepsis hispidus L.* may be mentioned as an example. Poisoning with Tetrodon has, however, been more accurately studied, and may be referred to at greater length under the term Fuguismus.

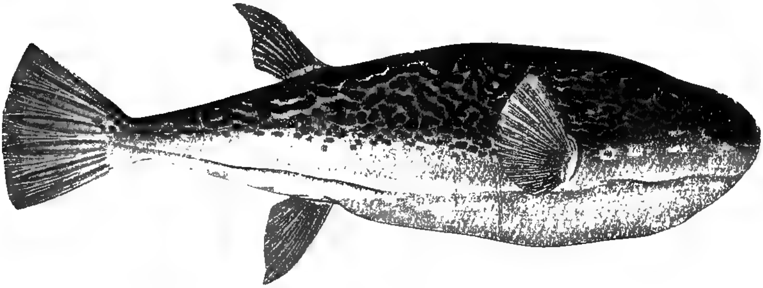

FIG. 20.—TETRODON VERMICULARIS SCHLEGEL.

(From Savtschenko's 'Atlas of Poisonous Fish.')

Fuguismus.

The Japanese term 'fugu' includes several species of fish belonging to the genus Tetrodon, of which the important species are *T. vermicularis*, *T. rubripes*, *T. laevigatus*, *T. chrysops*, *T. rivulatus*, *T. lunaris*, *T. pardalis*, *T. porphyreus*, *T. poicelonotus*, *T. stellatus*, and *T. sticonotus*, which are said by Scheube to be often used for suicidal purposes.

The poison appears to lie in the ovaries and testicles, which, according to Tabara, contain—1. Tetrodin—a crystalline base; 2. Tetrodonic acid—a white, waxy body. Both are poisonous, but the acid is said to be more so than the base.

The symptoms, which begin in three to fifteen minutes after eating one roe, are, according to Scheube, an unpleasant sensation in the stomach, abdominal pains, burning in the fauces, nausea, severe headache, collapse, and fainting. Death may occur in a few hours from paralysis of the heart or respirations. The mortality is high, being said to be more than 68 per cent.

The treatment is to empty the stomach with an emetic and to give stimulants, especially hypodermics of strychnine.

Post-Mortem Decomposition.

Post-mortem changes are much more rapid in the tropics than in the Temperate Zone, and, therefore, food is quickly apt to become poisonous. Meat is especially liable to become infected with saprophytic or pathogenic micro-organisms, especially *Bacillus paratyphosus-B* (Schotmüller) and the bacillus of Gärtner, more rarely *B. paratyphosus-A* (Schotmüller). These micro-organisms give rise to ptomaines, which cause symptoms of irritant poisoning (kreotoxismus), which may be so severe as to resemble those of cholera. The treatment is to remove the poison by emetics if necessary and purgatives, in the meanwhile keeping up the heart's action by means of warm applications, stimulants, and cardiac tonics. When collapse sets in, saline hypodermic injections should be given. As soon as the acute symptoms subside, the bowel should be disinfected with small doses of calomel, salol, or naphthol.

2. VEGETAL FOOD POISONING.

Sitotoxismus, or vegetal food poisoning, is caused by many kinds of vegetal food, and ought to be well known, but, unfortunately, is by no means on a scientific basis in the tropics.

Ergotism, well known in the temperate regions, is not important in the tropics; but, on the other hand, there is lathyrism, believed to be due to *Lathyrus sativus*, and other species of the same genus—loliismus, due to *Lolium temulentum*; and paspalismus, due to *Paspalum scrobiculatum*—which are known to occur in India. Less known is atriplicismus, which is described in China.

Kirke has drawn attention to poisoning by *Cystisus cadjan*, by which he probably means *Dolichus catjana* (Linné), named *Vigna catjang* (Walp) by Dragendorff, and also by *Dolichos filosa* (Klein), which is the same as *Vigna filosa* (Savi), both of which are used as foods. With regard to the former, the native name of which is urhu or toar, he says it mainly affects the poorer classes, as they do not remove the outer skin before eating it. The symptoms in the order of appearance are as follows:—Urticaria, sense of heat in the stomach, redness of the lining membrane of the mouth, apparent elongation of the teeth (by this must be meant shrinking of the gums), discoloration, bronzing of the skin, sponginess of the nails burning of the hands and feet, a dry, harsh, cracked condition o the cuticle of the hands and feet, and deep longitudinal cracks in the heels. Rheumatic pains, with thickening of the periosteum especially of the shins, and changes in the joints are also noticed

Dolichos filosa, called oordh dal, is said by Kirke to be poisonous only if eaten with the husks, when it causes colic, indigestion, and as secondary results rheumatic pains, harshness, and dryness of the skin, with cracks. It is said to be a staple article of food among all classes, except the highest and the lowest.

Lathyrismus.

Synonyms:—Platterbsenkrankheit (Ger.); Meurd Djilben (Algeria), Latirismo (It.).

Definition.—Lathyrismus is an intoxication caused by the ingestion of *Lathyrus sativus* Linnæus and other species of the same genus, and characterized by symptoms of spastic paraplegia.

History.—It is believed that Hippocrates was acquainted with the disease, because he mentions that people at Ainos who fed continually on pulse suffered from weakness in the legs. In 1671 the Grand-Duke of Würtemberg issued an edict forbidding the eating of bread made from vetch-seeds, as it had been noticed that those who ate such bread suffered from a peculiar stiffness of their legs, although they seldom died. In 1784 an epidemic was recorded in Tuscany, when, through scarcity of food, the people were compelled to eat chick-peas. Tozzetti, while studying this epidemic, came to the conclusion that only the people who had for at least three months eaten bread made of two parts chick-pea to one part of rye or wheat became ill. He then planted some of the chick-pea seeds, and, when they grew up, identified them as *Lathyrus sativus* (L.). In 1824 Desparanches came to the conclusion that the seat of the lesion was in the lumbar cord. In 1833 the disease was first recognized in India in the Sangor territories, where, on account of three successive famines in 1829-31, the people were compelled to eat vetches, which are called kesari dal, or teori. Outbreaks took place in Sind, Chota Nagpur, the Central Provinces, and in the Himalayas. It apparently became very prevalent, for Irving says that in one district 6 per cent., and in another 3·19 per cent., of the inhabitants were affected. It still exists in India.

Climatology.—The disease depends upon social rather than climatic conditions, for people will not eat the vetches unless compelled by famine. It is known in India, Algiers, Italy, and France.

Ætiology.—There appears to be a consensus of opinion that the disease is due to eating bread composed largely of flour obtained from seeds of some species of Lathyrus belonging to the natural order Leguminosæ. The species most commonly suspected is *Lathyrus sativus* Linné, which grows in India; but *L. cicera* L. (red vetch), *L. clymenum* L. (Spanish vetch), *L. tuberosus*, and *L. aphaca* have all been regarded as possible causes. It is, however, by no means evident what substance or substances in these plants cause the symptoms. Teilleux obtained a resin which caused tetanic spasms and paralysis of the posterior limbs in rabbits. Bourlier obtained an extract which killed birds and frogs. Asher obtained from *L. cicera* a volatile alkaloid, which he called lathyrin, which was doughy in consistence, alkaline, insoluble in water, slightly soluble in ether, soluble in chloroform, and which on evaporation formed needles; but he did not perform any experiments with the substance, the action of which is therefore unknown. It is believed by some that Lathyrus is not poisonous unless the seeds are decomposed or contain some parasitic growth, while others hold that the symptoms are not due to Lathyrus at all, but to *Agrostemma githago* (the corn-cockle) or *Lolium temulentum* (the darnel).

Animals are by no means immune from the baneful effects of the plants, for ducks become paralyzed and may die after eating the seeds; while pigs and horses also suffer, the latter showing acute or chronic symptoms which are said more or less to correspond to lathyrismus. On the other hand, bullocks and buffaloes are considered to be immune.

The great predisposing cause in man is scarcity of food, whether due to famine or poverty, both of which compel the unfortunate people to eat vetches instead of ordinary food. If the disease is brought about by famine, it may assume epidemic proportions; if by poverty, it may be simply endemic. Young people are more liable to be poisoned than old persons, and men more than women, perhaps because they eat more food.

Morbid Anatomy.—The pathology and morbid anatomy need investigation. When this is done, it is probable that some lesion of the pyramidal tracts—*i.e.*, of the upper motor neurones—will be found.

Symptomatology.—The incubation period is not known, and the disease comes on so insidiously that the patient often attributes it to a chill which he may have experienced a day or so previously.

Prodromata are often said to be absent, though it is more probable that digestive disturbances, colicky pains, and diarrhœa do occur, but pass unnoticed.

One of the first symptoms to arise is pain in the back and weakness in the legs, which increase until symptoms of spastic paraplegia appear. The patient now complains of girdle sensations, and walks with difficulty. The gait is characteristic, for the feet are turned slightly inwards, and are dragged or raised with difficulty from the ground. The joints appear so weak that it is difficult to proceed any distance without falling, while the body has a peculiar up and down motion. There is no ataxy, and no vasomotor phenomena, but the legs waste very much. The arms are not, as a rule, involved, though the hands may tremble. The superficial and deep reflexes are increased, and ankle clonus is present. The electrical excitability of the affected muscles is diminished, but the reaction of degeneration is absent. Incontinence of urine and impotence are early and common symptoms. The mind is unaffected.

The disease does not itself end fatally, but a definite improvement is seldom seen except in incipient cases.

Diagnosis.—Lathyrism must be distinguished from ergotism by the absence of gangrene, from beri-beri by the absence of implication of the peripheral nerves and the heart, and the absence of dropsy.

Prognosis.—The disease itself is not fatal.

Treatment.—Mild cases may be considerably benefited by being given good food and warm clothing, together with counter-irritation to the spine, and bromide of potassium internally in 15-grain doses three time a day. Strychnine is harmful.

Prophylaxis.—The only possible prophylaxis is the distribution of good food to the poor in times of famine.

Loliismus.

Loliismus is an intoxication caused by the ingestion of the seeds of *Lolium temulentum* Linné in bread.

History.—Loliismus has been known since Roman times, and is said by Orfila to have occurred in Genoa during the blockade of the year 1800. Kingsley of Roscrea described an outbreak in 1854, in which thirty persons suffered severely. Similar cases have been reported in India from the Punjaub, where the herb is called mostaki, and from the North-West Provinces, where it is called moschni.

Ætiology.—The exact method by which *Lolium temulentum* causes disease is not known. Dr. Cordier experimented on himself by taking 6 drachms of the seeds early one morning, and asserts that the result was inability to think, indistinct vision, torpor, debility, and drowsiness, followed by efforts to vomit, and later by tremors of the limbs, great depression, difficulty of speech, and vomiting. Bley separated a bitter principle, which he called loliin, but the action of this does not appear to have been investigated properly. Freeman states that the seeds owe their poisonous properties to an associated symbiotic fungus, which he carefully describes, and says that it is probably identical with that found in other species of Lolium. He says that it is a disputed point how far ergot and other fungi may be concerned in the production of the disease.

Climatology.—It occurs in the Punjaub and the North-West Provinces of India, and in Europe.

Pathology and Morbid Anatomy.—Not known.

Symptomatology.—The affected persons become very giddy, and stagger about as though drunk, and at the same time suffer from violent tremblings in the arms, legs, and tongue, impairment of vision with dilated pupils, green vision, great prostration, and in some cases vomiting. Sometimes there is a sense of burning heat in the mouth and throat, and a small irregular pulse.

Diagnosis.—The diagnosis may be effected by considering the symptoms and examining the bread, when the starch granules of Lolium may be seen.

Prognosis.—The disease does not end fatally.

Treatment.—Castor oil must be given to remove the poison, and at the same time stimulants must be used to counteract the collapse.

Prophylaxis.—Bread should not be made with the seeds of *Lolium temulentum*.

Paspalismus.

Paspalismus is an intoxication caused by eating bread made from flour derived in part from the seeds of *Paspalum scrobiculatum* Linné.

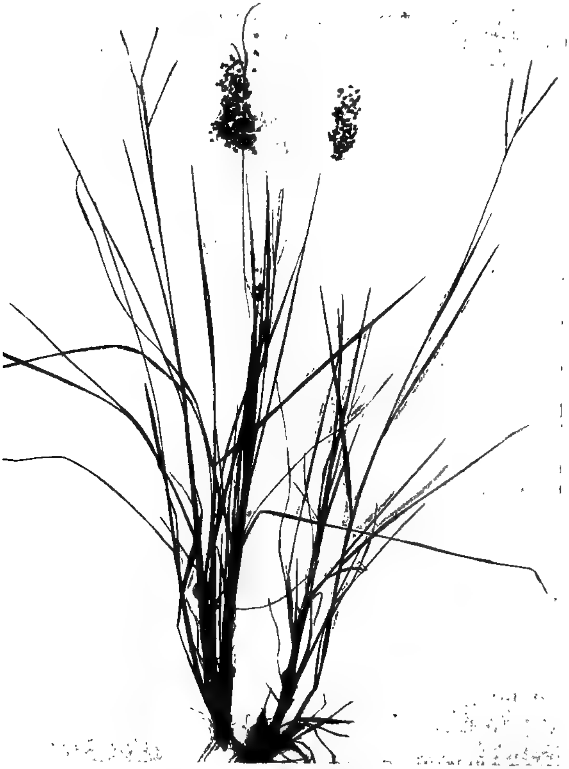

FIG. 21.—PASPALUM SCROBICULATUM LINNÆUS.
Seeds show separately at the top of the illustration.

History.—Poisoning by *Paspalum scrobiculatum* occurs in India, where it was reported as far back as 1879, and probably was known earlier.

Ætiology.—Some authorities doubt the genuineness of this disease, for, as Waddell points out, the symptoms are so like loliismus that it is quite possible that some mistake may be made as to the causation.

Two varieties of *Paspalum scrobiculatum* are known in India—viz., the sweet, which is called 'pechadi,' or 'goraharik,' and is said to be wholesome; and the bitter, which is called 'dhome, majara harik' or 'mana kodra,' and is considered to be poisonous. The poison appears to reside for the most part in the testa, but the exact poisonous principle is not known. Barry points out that the seed is liable to the attacks of fungi, and that perhaps the poisoning is really due to these parasites. It is clear that the whole subject requires revision.

Symptomatology.—The symptoms are vertigo, impairment of vision, apparent intoxication, muscular tremors, feeble pulse, cold clammy skin, dysphagia, delirium, narcosis, ending at times in death.

Diagnosis.—This must be mainly from poisoning due to Lolium, which can only be done by making inquiries as to the seeds from which the flour is prepared.

Prognosis.—This appears to be on the whole good, though fatal cases have been recorded.

Treatment.—Similar to loliismus.

Prophylaxis.—Avoid the seeds of the grass in making flour.

Atriplicismus.

Atriplicismus (Matignon, 1898) is an intoxication said to be caused by the ingestion of certain species of Atriplex (Linné), especially *Atriplex littoralis* L. and *A. angustissima vel serrata.*

History.—Atriplicismus was first described by Matignon in North China (Pekin) in 1898, but he leaves the subject open to some doubt.

Climatology.—The disease is, as far as is known, confined to China.

Ætiology.—In some way the disease is connected with *Atriplex serrata* (Chenopodiaceæ), which grows as a weed in the courts, gardens, and along the walls of the houses of Pekin, and is eaten by very poor people either uncooked or as a pancake.

It is said never to be poisonous if well washed, and if the red leaves are picked out. But Matignon drew attention to the fact that a small insect of a greenish-yellow colour is found on the plant. It is possible that the disease may be due to this insect, because Mégnin found that *Holothyrus coccinella* Gervais, a mite found in Mauritius and the Malay Archipelago, causes severe inflammation of the part touched. This insect may be carried by the hand to the mouth. Laveran thinks that the people get the thumb and forefinger infected while plucking the herb, and that it is by the hand that the disease is carried to the mouth. The ætiology is, therefore, extremely doubtful, and it may be either an animal or a vegetal poisoning.

The predisposing cause is scarcity of food, which compels the poorer classes to use some substitute for the usual cereals. Hence in Pekin in 1895, while the Japanese War was proceeding, there were a number of cases among beggars. Women suffer more than men, and the young and the old are specially attacked.

Morbid Anatomy.—The pathology and morbid anatomy are quite unknown.

Symptomatology.—The disease begins suddenly without prodromata, some ten to twenty hours after the plant has been eaten. The tips of the fingers and the back of the hands begin to itch, though sometimes the irritation may be at first limited to the thumb and forefinger. The affected parts soon become painful, swollen, cyanosed, and cold, while the pain and swelling spreads up the hands on to the forearms. The face and eyelids itch, and in due course become swollen, and the nose becomes cyanosed and cold. Sensibility to touch is diminished in the affected parts, but much increased to heat and to the sun's rays. Bullæ and ulcers may appear on the affected parts, the latter often giving rise to keloid scars. There is considerable itching. Ecchymoses may appear in various parts of the body. Gangrene of the fingers may also occur. The general health of the patient is not much affected.

Diagnosis.—Atriplicismus may require to be diagnosed from Raynaud's disease and erythromelalgia, but there should be no difficulty, because in the former there is no œdema, and in the latter there is redness as well as œdema.

Treatment.—The treatment is symptomatic, and consists in applying anodynes and cold compresses locally, and giving purgatives and disinfectants, such as salol, internally. Good food and good hygiene are also requisite.

Prophylaxis.—The ætiology must be settled before definite rules for prophylaxis can be given.

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CHAPTER VIII

TROPICAL INTOXICATIONS (*continued*)—VENOMOUS ANIMALS

Protozoa—Cœlenterata—Echinodermata—Platyhelmia—Nemathelminthes—Arthropoda—Arachnida—Scorpionidea—Aranea—Acarina—Chilopoda—Hexapoda—Siphunculata—Hemiptera—Hymenoptera—Lepidoptera—Diptera—Coleoptera—Mollusca.

VENOMOUS ANIMALS.

MANY species belonging to the various classes and orders of the animal kingdom possess glands which secrete chemical substances injurious to man and the higher animals. The exact nature of these chemical substances is but little understood at present, though of late years much advance has been made in the knowledge of their action, which seems to be of a nature similar to that of bacterial toxins.

It will be best to consider these venomous animals in the order of their zoological classification.

PROTOZOA.

Rosenau and his collaborators have recently succeeded in producing a malarial paroxysm in a healthy man by injecting blood-serum taken from a malarial patient during the cold stage of the fever, and previously filtered through a Pasteur-Chamberland filter. Casagrandi and De Blasi have also described a hæmolytic toxin, concerning which more will be said when malaria is discussed.

Laveran and Mesnil have shown that *Sarcocystis tenella* produces a toxin, sarcocystin, of which 0·1 milligramme will kill 1 kilogramme of rabbit with choleraic symptoms, while a less dose will produce fatal cachexia. It is, however, less toxic to other animals.

CŒLENTERATA.

The Cœlenterata include anemones, corals, and jelly-fishes, which are capable of stinging by means of certain special cells called cnidoblasts, which enclose nematocysts—*i.e.*, little sacs—the invaginated neck of which is continued into a long, hollow, spirally coiled filament, surrounded with poisonous fluid. When stimulated, these cysts explode, and the filament is ejected and pierces the skin of the animal attacked, and so introduces the poison.

Zoantharia.—Stings from anemones cause itching and burning and skin eruptions. In its worst form this is exhibited in *la maladie des plongeurs* (*pêcheurs d'éponges*) of the Mediterranean. According to Dr. Skévos Zervos, the first symptoms are itching and intense burning in the place where contact with the anemone has taken place. A papule then appears, surrounded by a area, which at first is red, but may become blue and finally black, and may spread over the surrounding skin to a distance proportional to the virulence of the poisoning. The skin sloughs, and leaves a suppurating ulcer. Dr. Zervos has produced the symptoms of this disease in a dog by rubbing an actinia held in a forceps along its abdomen.

C. Richet has separated two poisonous principles from *Anemone scultatus*—viz., thalassin and congestine. Thalassin is not very toxic, producing cutaneous redness, intense congestion of mucous membranes, pruritus, and sneezing. Congestine is much more virulent than thalassin, for a dose of 2 milligrammes per kilogramme will kill a dog in twenty-four hours. Thalassin is, however, antagonistic to congestine, for a dog inoculated with the former will resist an otherwise mortal dose of the latter.

The application of fat to the skin is said to be a preventative to the venomous action of the anemone.

Millepora.—Jones has described an acute erythema, with severe pain, followed by papules, pustules, and desquamation, as the result of stings by the hydroids of the hydrocoralline millepores (*Millepora alcicornis*, *M. complanata*, and *M. verrucosa*) in Malaya, where the corals are known as 'Karang gatal,' or itchy corals.

Trachymedusæ.—The jelly-fishes of European waters, such as *Rhizostoma pulini* of the Mediterranean and *R. cuvieri* of the English Channel, are well known to cause local redness, swelling, and urticarial eruptions.

The jelly-fishes of the tropics produce the same symptoms, but with greater severity. The pain is agonizing, and there is collapse, with local swelling and redness.

The treatment is to give stimulants internally, and to apply alkalis, such as dilute ammonia, to the affected area. Usually recovery is quick, and there are no after-effects.

Meyer describes a case of poisoning due to the well-known *Physalia pelagica* (the Portuguese man-of-war), in which there was severe inflammation and fever. A similar case caused by *Cyanea capillata* has been recorded by Forbes.

Porter and Richet obtained a liquid from Physalia containing an active principle, hypnotoxin, which, when injected into animals, caused somnolence and finally death, due to cessation of respiration.

said to cause inflammation of the skin, and, if any of the secretion gets into the eye, even blindness.

PLATYHELMIA.

Dibothriocephalus latus, which causes a profound anæmia, is suspected to secrete some form of poison, and, indeed, this theory is supported by certain experiments of Schaumann and Tallquist. These investigators found that if the worms were subjected to tryptic digestion, and then mixed with food and given to dogs by the mouth, or extracted with normal salt solution and injected hypodermically, an exhaustion which ended in death was sometimes produced. In one case there was a great reduction of the red blood-corpuscles. Rabbits, however, were not affected.

Tænia saginata has been investigated by Messineo and Calamida, who consider that they have found evidence of the presence of a poison which can be obtained by pulverizing the tænia with sand and extracting with normal saline solution. This extract was then filtered and injected into animals, but the symptoms were not characteristic. Picou and Ramond consider that the extracts they obtained showed a decided bactericidal action.

On the other hand, the rupture of an echinococcus cyst is well known to produce symptoms of poisoning, but the chemical nature of the poison is not known. The symptoms in man are urticaria, if the dose is small; peritonitis, and severe cardiac symptoms, leading to fatal collapse, if the dose is large. Injected into animals, the liquid acts as a cardiac poison, causing death by stoppage of the heart in diastole, together with various other symptoms, such as a fall of the blood-pressure and temperature.

NEMATHELMINTHES.

Ascarides produce a volatile body with a peculiar and disagreeable odour, very irritating to the mucous membranes, especially to the conjunctiva. This odour is most noticeable in making post-mortems upon persons suffering severely from these worms. Arthus and Chanson have injected rabbits with the liquid squeezed out of living human ascarides, and produced collapse and death within ten minutes of a dose of 2 c.c.

Cattaneo obtained a substance toxic to guinea-pigs by allowing ascarides to live in sterile broth. Cao, Jammes, Mandoul, and Boycott, however, failed to obtain any evidence of the toxicity of ascarides.

With regard to *Agchylostoma duodenale*, there has been much discussion as to whether it produces a toxin or not. The experiments of Whipple and Preti seem to establish the presence of a hæmolytic principle in the alimentary canal of the worm, and those of Loeb and Smith of a principle inhibiting the coagulation of the blood and secreted by the cephalic glands, but these substances appear to be of importance to the worm for the purposes of digestion, and not to be of sufficient strength to act upon the host. According to Alessandrini, however, the cephalic glands secrete a true toxin. The evidence which has been gathered together points also to the possibility of the toxicity of the agchylostomes being partly due to the absorption of bacteria or their products into the circulation of the host through lesions in the intestinal mucosæ caused by the bites of the worms.

ARTHROPODA.

The Phylum Arthropoda includes a large number of types, which are characterized by their capability of stinging.

I. ARACHNIDA.

The class Arachnida includes among its orders the Scorpionidea, or scorpions, the Aranea, or spiders, and the Acarina, or mites and ticks, many of which are venomous.

1. Scorpionidea.

Scorpions abound in the tropics, where they grow to a large size, and are much feared because of the poisonous properties of their sting. The method of striking is to bring the tail forward over the body of the scorpion, so that the curved spine on the last segment (telson) of the tail penetrates into the skin and inflicts the wound. On either side of this curved barb is an opening through which the duct from a poison gland discharges the venom.

It is probable that the poison of different kinds of scorpions differ qualitatively and quantitatively, but on this subject little is known. Certainly the sting of the small European scorpion (*Euscorpius europæus*) has but slight action, causing only local pain, redness, and swelling, while the larger one of South Europe (*Buthus occitanus*) causes severe pain and phlegmonous swelling of the whole extremity, and such remote symptoms as vomiting, faintness, tremors, and cramps in muscles, while the larger tropical species kill not merely children, but even men. According to Cararoz, as many as 200 persons die annually from scorpion-sting in the neighbourhood of Durango in Mexico. In Africa scorpion-stings are of frequent occurrence, but death is rare.

Historical.—Maupertius in 1731 and Redi in 1779 appear to have been the first to study the effects of scorpion-venom by experiments, though the ancients were well acquainted with the sting and its effects, and had woven wonderful legends as to the origin of these animals. Redi experimented upon a pigeon and a dog, but the real study of the venom began with Guyon 1864, Paul Bert 1865, Delange 1866, and Valentin in 1876, and was followed up by Joyeux-Laffine in 1883 and many others. A full literature is given in Faust's 'Die Tierischen Gifte.'

Geographical.—Scorpions occur all over the world, but the largest and most dreaded are found in the tropics. They live under stones, under the bark of trees, in sand, and also in houses, which they leave at dusk. Some of the best known are:

1. *Euscorpius europæus* (3 to 3·5 centimetres long): Italy, Tyrol, South France.
2. *Buthus occitanus* Amour (8·5 centimetres long): Italy, Greece, Spain, North Africa.
3. *Buthus afer* Leach (16 centimetres long): Africa, Asia.
4. *Buthus quinquestriatus* Hemps and Ehrenbg.: Upper Egypt and the Sudan.
5. *Buthus maurus*: Egypt, Tunis.
6. *Prionurus citrinus*: Desert near Cairo and Alexandria.
7. *Prionurus amoureuni* Savigny: Sudan.
8. *Androctonus funestus* Ehrenb. (9 centimetres long): North and Middle Africa.
9. *Heterometrus maurus*: Tunis.

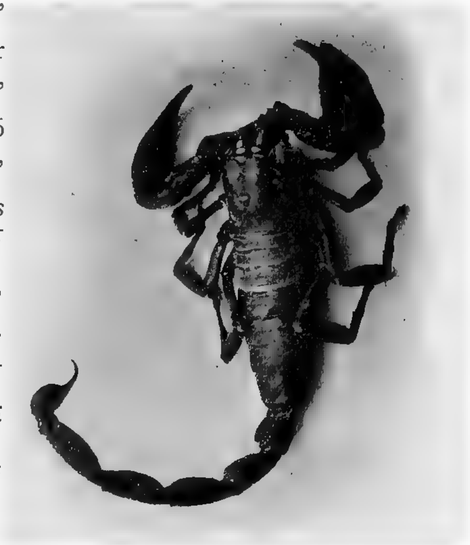


FIG. 22.—PALAMÆUS INDUS.
(A scorpion commonly found in Ceylon.)

Anatomical.—The body of the scorpion is divided into a cephalo-thorax or prosoma, behind which comes an abdomen subdivisible into a broader portion, or mesosoma, and a narrower, metasoma, with five segments, which is popularly called the tail. At the end of this metasoma there is a postanal curved spine, called the telson, inside which lies the paired poison gland. The appendages of the scorpion are: 1. Small three-jointed chelicerae, which are used for holding prey. 2. Large six-jointed pedipalpi, which are used for seizing prey. 3-6. Four pairs of seven-jointed walking legs.

Scorpions seize their prey with the pedipalpi, hold them close to the mouth by means of the chelicerae, and sting them, if necessary, by bringing the metasoma forwards over the mesosoma and cephalo-thorax, and inserting the tip of the telson well into the animal's body, and allowing it to remain there until the poison has had time to act. The telson consists of two portions—a broad swollen part (the ampulla) and a narrow portion (the spine), near the extremity of which are two small openings for the escape of the venom. The two poison glands lie inside the ampulla, one on each side of the middle line. Each gland is covered with a sheet of muscle on its mesial and dorsal aspects. This muscle, which is called by Wilson 'the compressor,' is inserted by its edge mesially along the ventral inner surface of the wall of the telson, and by a broader insertion laterally. The compressor muscle squeezes the poison out of the gland, along the duct, and through the opening in the spine into the victim. The epithelium of the gland shows three distinct types of cells—the mucous cell, the fine oxyphile granular cell, and the cell with very large granules.

The Venom.—Scorpion-venom is a clear, faintly acid fluid of a somewhat thick or oily consistence, and possessed of an extremely faint yellowish colour. It contains no structural elements, but crystals form in it if evaporation takes place. On an average it contains about 28 per cent. of solids.

Wilson gives the following figures for the venom of *Buthus quinquestriatus :*

Specific gravity	1092
Solids	20·3 per cent.
Ash	8·4 ,,

Proteids form part of the solids, and it is believed that the active principle is either a nucleo-proteid, acid albumin, or a primary proteose. The effects described by various authors would, however, indicate the presence of toxins, one resembling the neurotoxin of snake-venom, and another a hæmolysin, for Kyes has described a typical lecithide producing hæmolysis like the lecithides of cobra-venom. Calmette has also shown that the venom of *Buthus occitanus* is neutralized by cobra antivenene. There would, therefore, appear to be some resemblance between scorpion-venom (or, at all events, the venom of *Buthus occitanus*) and cobra-venom. It is, however, impossible to make any definite statements, as the condition of our knowledge with regard to this poison is most unsatisfactory.

Joyeux-Laffine thought that the venom first increased reflex action, and then caused paralysis of the nervous system, and that death was due to a curari-like poisoning of the end-plates of the respiratory muscles ; but Valentin found these were quite intact, and that the muscles contracted well when their nerves were stimulated by electrical or mechanical stimuli.

As regards the action on the blood, coagulation, hæmorrhage due to change in the capillary walls, and hæmolysis have been observed, as well as agglutination of the red corpuscles, which are said to form viscous masses, and thus to block the bloodvessels by embolism.

These observations were made by Jousset de Bellesme on *Lilla*

a frog remarkable for its lack of pigment, and therefore
ly suitable for such a purpose. If confirmed, they would
:he presence of fibrin ferment, hæmorrhagins, hæmolysins,
;glutinins in scorpion-venom, and would make it resemble
losely snake-venoms. Sanarelli, however, was not able to
e any change in the red cells beyond hæmolysis, which he
the blood of fishes, amphibia, and birds.

onclusion, we may therefore assume the presence of a neuro-
acting on the central nervous system, and the presence of
ysins, until further experiments give us more exact informa-

imum Lethal Dose.—The minimum lethal doses for dry *Buthus*
enom is, according to Calmette, 0·05 milligramme for white
and 0·5 milligramme for rabbits.

t the venom must be very toxic for small animals is shown
e fact that the minimum lethal dose for a guinea-pig is 0·1
'amme per kilogramme, which gives a toxic value of 10,000,000
thus quinquestriatus; but, as may be imagined, the toxicity
erent venoms varies considerably, and the difference may be
erely quantitative, but qualitative.

cts of the Venom.—It must be remembered that the venom
merely a means of defence for the scorpion, but it is also the
d by which it kills its prey, which usually consists of small
ls; and, further, that, in order to be toxic, the venom must
ected subcutaneously or intravenously, for by the mouth it is
ess.

en experiments are performed on animals, the following
:oms appear:

ocal irritation and pain.
Iuscular twitchings, chiefly of the head and neck.
umping movements.
achrymation.
ncreased orbital, nasal, and salivary secretions.
Iuscular spasms, especially of the hind-limbs, but also in all
es.
Erection of the hairs.
Passage of liquid fæces (often absent).
Erection of penis and emission of semen.

venom of *Heterometrus maurus* causes death in small birds
two minutes to half an hour from failure of the respiration.
venom of a scorpion is placed on the conjunctiva of a rabbit,
t ophthalmia results.

nan, the symptoms depend upon the size and nature of the
on. Thus, the sting of the small ($3\frac{1}{2}$ centimetres) *Euscorpius*
eus causes only pain, redness, and local swelling, whereas the
tropical scorpions cause very intense pain of a burning
:ter radiating from the skin, associated often with violent con-
ns, mental disturbance, and hallucinations, profuse perspira-
and secretion of saliva, and perhaps vomiting. The pulse is

weak and quick, and the respirations hurried and shallow. These symptoms gradually diminish in three to eight hours, and by about nineteen to twenty-four hours the person is usually normal. This, however, is not always so, for death may ensue due to collapse or stoppage of the respiration, effects which are more likely to happen in small children than in adults. Thus, Wilson states that the mortality in children under five is 60 per cent. for *Buthus quinquestriatus*, but the mortality diminishes as the age increases. Of course this is simply due to the greater dilution of the poison in the body of the adult.

In addition to the above symptoms, some authors have described trismus, but it is probably due to infection with the bacillus of tetanus. The erection of the penis noted in experiments on animals has been seen in man by Delange and Guyon in Algeria. A paralysis of the lingual and hypoglossal nerves has been noted by Posada-Arango. Lymphangitis and adenitis are described as part of the local effect of the sting.

The above symptoms would indicate the action of a neurotoxin acting upon the nervous system, and causing first of all increased reflex action and convulsions, and later paralysis of the medullary nuclei; for if Valentin's observations are correct, there are no paralyses of the motor nerve-endings.

Effect on the Scorpion.—At the present time it is not believed that a scorpion commits suicide when in difficulties by stinging itself in the head with its own sting, because, though not absolutely immune to its own venom, it possesses a high degree of immunity against it. Accidental but not intentional wounding of an individual by its own sting is said to be known.

Immunity.—A natural immunity exists in the jerboa (*Jaculus jacilis*) and in the desert rat (*Gerbilis pyramidis*), and a partial immunity in the zerilla (*Ictonix libyca*).

According to Balfour, fakirs at times possess an acquired immunity, but this has not so far been obtained in any animal. Calmette has reported that the serum of a horse immunized against cobra-venom can neutralize the venom of *Buthus occitanus*—a fact which Metchnikoff has confirmed; but Nicolle and Catouillard have found this serum useless against the venom of the Tunis scorpion (*Heterometrus maurus*).

Diagnosis.—The history of the case and the single puncture on the affected part makes the diagnosis generally easy.

Prognosis.—If an adult is stung, the prognosis is good, as death is known to be rare, but not so in children. The prognosis, therefore, varies with the age, and can be judged by the following table from Bray, quoted by Wilson, which gives the deaths at Omdurman in 1902 as follows:

Under one year	5
One to five years	9
Five to fifteen year	7
Total	21

ths of adults, however, are known, but generally take place ew days, not quickly.

atment.—The most reasonable treatment is to apply a proximal re, and to excise and treat the wound with permanganate of h, as described under the heading of Snake-Bite.

shing and bathing with a weak solution of ammonia may also ed, and stimulants should be given.

onel Duke recommends that 5 to 10 minims of a 5 per cent. on of cocaine be injected subcutaneously close to the sting in ult, and 1 to 5 minims in infants and children. Eucaine or ne might be preferable, and can be imported from any st in sterile capsules ready for hypodermic injection. Simpson mends the local application of a paste of ipecacuanha.

hough the experiments of Calmette with the venom of *Buthus nus* would indicate the trial of his antivenene in bad cases, he experiments of Nicolle and Catouillard indicate that the may not be satisfactory. Recently a serum has been pre- by Todd for the Board of Health Department of Egypt from 's blood, and has been found useful.

2. Aranea.

Aranea, or spiders, are found all over the world, but by far rgest are in the tropics, and their peculiarly repulsive appear- has given rise to numerous fables, both ancient and modern, egard to their poisonous properties.

torical.—The study of spider-stings may be said to be modern, begin with Blackwell in 1855, but it was Kobert in 1893 who the fundamental data concerning these poisons. He main- that, in addition to the secretion of the poison gland, there xalbumin which permeates every portion of the body of the l, and in some species of animals is mixed with the venom. nsiders that the secretion of the poison gland only gives local symptoms, and that the general symptoms are due to xalbumin, and that it is because of this admixture in *Latro-* that the bite may cause severe symptoms and even death man beings. The common European garden spider (*Epeira na*) only causes local irritation, because the toxalbumin, h present in the body, is not mixed with the poison of the gland. He also describes a hæmolytic action in both *Epeira atrodectus.*

hs has contributed a paper in which he carefully studies this lysin, which he calls arachnolysin, and Wilson has recently n an excellent monograph on the spider-bites.

graphical.—All genera of spiders appear to be poisonous, but ost important are: *Latrodectus mactans*, Chili; *L. scelio*, atipo of New Zealand; *Theraphosa avicularia* L., South ca; *T. blondi* Latr.; *T. javanesis* Walck.; *Chiracanthum* Walck.; *Theridium tredecim guttatum* F., France and Italy; *ubre* Koch, Kara kist of Russia; *Segestria perfida* St.;

hætopelina olivacea ; Lycosa tarantula L. ; *L. singoriensis* Laxman ; *peira diadema* Walck.

Anatomical.—The body of the spider is sharply divided into ephalothorax and abdomen. The pairs of appendages are six in umber :—(1) The two-jointed cheliceræ ; (2) The six-jointed legike pedipalpi ; (3-6) The seven-jointed legs. The poison gland sually lies in the basal joint of the chelicera, ensheathed in conective tissue, inside which there are two spirally arranged layers f non-striped muscle surrounding a basement membrane which ears two to three layers of polyhedral cells, surrounding the lumen f the acinus. From the gland the duct runs forwards into the istal hook-shaped joint, upon the apex of which it opens.

The Venom.—The venom, which is useful to the spider, enabling t to kill the small animals upon which it lives, is an oily, transucent, lemon-yellow-coloured liquid, with an acid reaction and a ot, bitter taste. It has proteid reactions, and gives the xanthoroteic reaction. It is difficult to obtain it in any quantity. Wilson ecommends triturating the gland with distilled water (0·5 c.c. being sed for each gland), and then filtering, when an extract suitable for xperimental purposes is obtained. These extracts are rendered armless by heating to 90° C., and the active principles are said ot to dialyze. The chemical peculiarities and the active principles f the venom are little known. Kobert, as has already been ointed out, considers that there are two poisons :—(1) A toxin ecreted by the poison gland, and only causing local symptoms ; 2) A toxalbumin distributed through the body (not originating rom the poison gland), and causing general symptoms. The first xists alone in *Lycosa tarantula, L. singoriensis.* The second largely redominates in *Latrodectus.*

Kobert and Sachs have found and studied a hæmolysin, arachnoysin, in the venom of several kinds of spiders, and Sachs has been ble to immunize a guinea-pig against this toxin and produce an ctive serum. Arachnolysin acts upon the red cells of man, rabbit, x, mouse, and goose, but not on those of the horse, dog, sheep, nd guinea-pig.

Spider venom is also said to increase the coagulability of the lood. The venom of *Theridium lugubre* is believed to act inuriously on the isolated frog's heart, even when diluted to 1 in 100,000, but it is not known whether this is due to action irectly upon the heart-muscle or upon the local nervous apparatus. he walls of the capillaries are also said to be damaged by spider-venom, and to allow an increased amount of transudation, and ence the hæmorrhages and œdema seen about the wound. It is asserted that the venom acts deleteriously upon the mucous membrane of the stomach and intestines, causing redness and swelling, and even hæmorrhages, which perhaps are due to some attempt at excretion of the poison by these organs. It is also thought that the venom acts upon the central nervous system, but whether the cramps and convulsions are really due to action of the oison upon the nerve cells, or merely to the altered blood conitions, has not been decided.

The reader is particularly asked to compare these actions on the ervous system (neurotoxin ?), on the mucosa of the stomach, on e capillary wall, on the blood and red cells, with the venoms of e scorpion and of the snakes, which they strongly resemble.

Acquired immunity can be produced in animals by injections of on-lethal quantities of venom.

Minimum Lethal Dose.—The minimum lethal dose for cats is ·20 to 0·35 milligramme of the dry venom per kilogramme of the ody-weight. Dogs are less sensitive, and hedgehogs still less, hile frogs require fifty times the quantity of poison which will ffect warm-blooded animals.

Effects of the Venom.—In general, the symptoms of spider-bite ather resemble those of the scorpion, and are divisible into (1) local, 2) general. Local inflammation is generally present, but may be bsent, and severe pain is felt at the site of the wound. The general ymptoms are those of collapse coming on gradually, with someimes convulsions, or rarely a typhoidal condition ensues, which may emain for weeks. Many other symptoms may also be noted, such s nausea, rigors, cold sweats, dyspnœa, fever, delirium, paralysis, nd coma terminating in death. Inflammation of the stomach and ntestines, coagulation of the blood, and local hæmorrhages and edema, are the principal features of a post-mortem examination. he symptoms of the bites of the different spiders will now be riefly described.

Bite of Latrodectus mactans.—The symptoms of this bite are local ain, which does not appear till some little time after the bite, but ecomes agonizing, and may last for a couple of days. In addition, etanoid symptoms may set in, but usually end in recovery in about en days.

Bite of Latrodectus scelio.—This is the katipo spider of New ealand. The symptoms begin in about thirty minutes with the ormation of a white vesicle surrounded by a red halo, and severe ain at the site of the bite. The general symptoms include, first, tiffness of the muscles about the mouth and jaw, so that it is ifficult to open the mouth or to speak, and impossible to swallow. he pulse becomes very slow (12 to 14 to the minute), and there s extreme pallor of the face and body, with coldness of the exremities, which are quite flaccid. Respiration becomes slower and lower, and death may take place at this stage, or an illness lasting bout six weeks, and somewhat resembling typhoid, may ensue, hich may end either in death or recovery.

Bite of Theridium lugubre.—This bite is characterized by smartng pains, no redness or swelling, cold sweats, restlessness, dizziness, ental anxiety, depression, vomiting, cyanosis, convulsions, status yphosus, and, unless improvement sets in, death in three days.

Bite of Theraphosa avicularia.—The Theraphosæ come under the ommoner heading of Mygale, and cause prolonged inflammation and extensive cicatrization. *Theraphosa javanensis* is reported to kill men.

Bite of Chætopelina olivacea.—The local symptoms are great pain, redness, swelling, but whether a general effect (curari-like poisoning of the voluntary muscles and death from stoppage of respiration) takes place is very doubtful.

Bite of Lycosa tarantula.—The bite of this spider produces wheals surrounded by a red areola, but no general symptoms result, and tarantismus only exists in popular imagination. The tarantula dance was probably introduced as a cure, with the purpose of keeping the patient on the move, so that he should perspire, and hus get rid of the poison. The tradition of the Middle Ages was hat the bite caused the dance frenzy, *Chorea saltatoria*, or taranismus, which was supposed to lead to such violent exertion that death resulted unless the victim was soothed by music.

The Bite of Epeira diadema.—The bite of the common garden spider has been recently proved by Kobert and Sachs to be poisonous.

The Bite of a Bengal Spider.—Fink has recently described a herpetic ruption on the face of Bengalee children due to a spider-bite; for this he recommends fumigating the face with the smoke evolved when lumps of mustard-oil cake, burned in a charcoal fire, are dropped into a basin of cold water.

Diagnosis.—Bee-stings, scorpion-bites, and ordinary skin bacterial nfections must, of course, be distinguished from spider-bites, with which, without doubt, they have been often confounded. The ocal symptoms and the history ought to be some guide.

Prognosis.—This is generally good.

Treatment.—Prevent absorption by the proximal ligature, open he wound by an incision, and apply alkaline solutions—*e.g.*, weak olutions of ammonia or carbonate of potash. It appears to us hat a strong permanganate of potash solution ought to be given a trial.

3. Acarina.

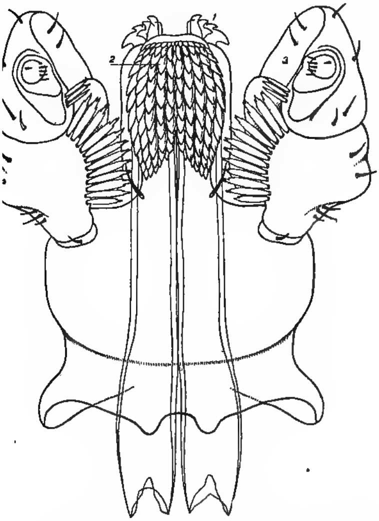
The Ixodoidea, or ticks, are well known to cause severe symptoms by their bites, apart from the introduction of any parasite such as a *Babesia* or *Spirochæta*.

The anatomy of these arthropods is given in detail in Chapter XVII., to which reference should be made, but a few remarks are necessary concerning the act of biting, which has been recently studied by Nuttall.

The tick pierces the skin by means of the teeth on the digits of ts chelicerae. The digit is capable of being extended by an internal muscle, and turned outward by an external muscle. These movements, occurring alternately, cause the teeth to cut the skin, and as the chelicerae work deeper and deeper, the hypostome is dragged nto the wound, and by its recurved teeth keeps the tick in position. The palps but rarely enter the wound. During this act of biting t is believed that the salivary glands pour a considerable amount secretion into the victim, but the nature of this fluid and its tion requires further investigation. Nuttall, drawing attention the immunity following bites, says that it is probable that this cretion is toxic in its action.

The Effects of the Venom.—With regard to the Argasidæ, *Argas rsicus* Oken has an evil reputation in Persia, where its bite is said cause severe pain, fever, lassitude, delirium, convulsions, and en at times death in new-comers, while natives are immune.

Bordier considers that these symptoms are due to the injection a poison, but this would hardly appear to be likely, as Lounsbury und in his own case in South Africa that the bite caused only ight itching. If the symptoms are properly described in Persia, would indicate that the tick introduced some parasite into the ew-comer which caused a definite disease to which the native ad acquired an immunity.



G. 23.—Ventral Aspect of the Mouth-Parts of a Tick (Hæmaphysalis punctata Canestrini and Fanzago).

After Nuttall, Cooper, and Robinson, *Journal of Parasitology*.)

1, Chelicerae, showing teeth; 2, hypoome, showing rows of recurved teeth; palp.

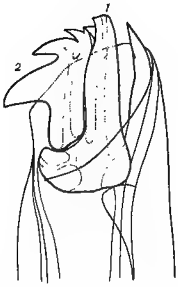


Fig. 24.—Chelicera from the Same Tick.

(After Nuttall, Cooper, and Robinson, *Journal of Parasitology*.)

1, Internal digit; 2, external digit.

Argas reflexus Fabr. may cause local pain and swelling, with metimes an erythematous eruption, while the site of the bite is arked for years by a cicatrix. The bite of *A. brumpti* Neu is also vere.

Ornithodoros moubata Murray inflicts a very painful bite, with uch swelling and the formation of raised hard wheals, in Europeans, hich may last several days.

Ornithodoros turicata Dugès may cause swelling and numbness l over the body, with vomiting and diarrhœa, accompanied by an rticarial eruption and profuse perspiration, with rigors, fever, head- che, and backache if the poisons enter a vein. Locally, an ulcer ay form at the site of the bite. *O. talaje* Guérin Méneville causes vere itching and pain.

With regard to the Ixodidæ, *Ixodes ricinus* causes severe derma- tis, which may be followed by pustules and abscesses, with dema, lymphangitis, and lymphadenitis, associated with fever.

Treatment.—The treatment of tick-bites is first to detach the ck, which is by no means easy, as the recurved teeth of the hypo- ome hold on to the wound very firmly. The best plan is to rub y oil into the ventral surface of the tick, thus interfering with its spiration, and compelling it to detach itself from the host. With gard to *O. turicata*, it is advised to apply the actual cautery, so vere are the effects of the bite. According to Wellman, *Ornitho- ros* bites should be treated by bathing in very hot water, after hich bicarbonate of soda should be applied in strong solution. ching may be allayed by a menthol ointment (1-2 per cent.).

As regards prophylaxis, badly infected native huts should be rnt, while ordinary houses may be fumigated with sulphur or rbon bisulphide, or sprayed with kerosine or boiling water. Beds ust always be raised from the ground, and the feet of the bedstead aced in water containing kerosine, while pyrethrum powder may dusted between the coverings of the bed. Wellman insists that tives should not be allowed to sleep in or near the quarters of uropeans.

2. Chilopoda.

The class Chilopoda includes the Scolopendridæ, or centipedes, hich are animals with a head and a uniformly segmented trunk, ssessing numerous legs. They are very common all over the orld, but the tropical species are much larger than those which habit the Temperate Zone. They live under stones in shady aces, especially in woods. The poison apparatus of the centi- des is formed by the appendages of the first trunk segment being odified so as to form a large pair of jaws, at the base of which e poison gland lies. The duct of this gland opens on the apex of e claw, and therefore, as there are two jaws, a centipede-bite will ow two minute punctures or drops of blood.

The venom is primarily intended to kill their prey, which consists small insects and larvæ.

Geographical.—The most noted species are *Scolopendra cingulata*, ance, Spain, Italy; *S. gigantea*, *S. morsitans*, *S. heros*, Africa, dia, Indo-China, Equatorial America; *Geophilus longicornis* each, Mid-Europe.

he Venom.—The venom is an acid opalescent liquid, but little ible with water. For experimental purposes it can be obtained reating the lower lip and the hooks with normal saline solution. hen injected into the veins of rabbits, it causes an immediate lysis, with coagulation of the blood, while under the skin it ns a large abscess.

ffects of the Venom.—The poison causes local and general ptoms. At first there is itching, but this is quickly followed intense pain, which extends all over the limb. A red spot ears at the site of the bite, which enlarges and becomes black he centre, and sometimes there are lymphangitis and lymphnitis. The general symptoms are great mental anxiety, vomiting, gular pulse, dizziness, and headache.

iagnosis.—The diagnosis is obtained by the history and the ence of the two minute punctures.

rognosis.—The prognosis is good, though small children have n known to die from the effects of a sting. Adults, as a rule, ver in about twenty-four hours at the most.

reatment.—Bathe the part well with a solution of ammonia n 5 or 1 in 10). After bathing, apply a dressing of the same li, or if there is much swelling and redness, an ice-bag.

necessary, give hypodermic injections of morphia to relieve the n. At a later period, fomentations may be required to reduce local inflammation.

3. HEXAPODA.

he Hexapoda, or insects, contain many species injurious to n.

he orders to which the principal venomous species belong are: Siphunculata; (2) Hemiptera; (3) Hymenoptera; (4) Lepitera; (5) Diptera; and (6) Coleoptera.

1. Siphunculata.

his order includes the lice, which cause much irritation by their s. The nature of the venom, however, is not known, and the are of more importance as carriers of disease, and will therefore ealt with more fully in Chapter XVIII.

2. Hemiptera.

he Hemiptera include the families of the Cimicidæ, or bugs, and Reduvidæ, or cone noses. In the latter family is classified *nergates bicoloripes* Stäl, which, according to Wellman, produces ery painful bite in man in Angola. Another member of this ily, as yet not named, has been described by King in the an, where it bites human beings on the hands and wrists, ducing small red lumps, which, however, soon disappear. It is to be closely related to *Phonergates bicoloripes*.

It is, however, more convenient to discuss these venomous insects along with other parasites in Chapter XVIII., as it enables a more systematic description to be given, especially as the nature of the venom is quite unknown.

3. Hymenoptera.

In this order come the bees, wasps, and ants.

Apidæ.

The members of this family which sting are well known, and it is by no means infrequent to hear of animals and even at times human beings in the tropics suffering severely from bee-stings, and more rarely dying from the effects.

The species generally credited with evil effects are: *Apis mellifica* L., the hive-bee; *Vespa vulgaris* L., the wasp; *V. germania* Fabr.; *V. crabo* L., the hornet; *V. orientalis,* the hornet; *Bombus hortorum* L., the bumble-bee; *B. lapidarius,* and *Xilocopa violacea,* the wood-bee.

Historical.—The venom of the bee was first studied by Brandt and Ratzeburg in 1833, then by Paul Bert in 1865 and Carlet in 1884, but the chemical nature was first investigated carefully by Josef Langer in 1897.

Anatomical.—The body of the bee is divided into head, thorax, and abdomen, from the posterior end of the last of which projects the sting in the form of a chitinous sheath, narrow posteriorly and wider anteriorly. This sheath contains two barbed darts, and into its wider portion (which possesses a cleft by which air can penetrate into it) two or three ducts from glands open. The principal opening belongs to the duct of the 'acid gland,' and opens anteriorly into a sac—the poison reservoir—which leads into a long, slender, coiled tubular gland, either bifid anteriorly or subdivided into two glands. This long gland ramifies amongst the contents of the abdomen. The second opening, which lies alongside the first, belongs to a small, irregular, tubular gland called the alkaline gland, or gland of Dufour. The third opening, when present, leads into a lanceolate or ovoid accessory poisonous gland.

The Venom.—The venom freshly extruded from the bee's body weighs from 0·2 to 0·3 milligramme, and is a transparent acid fluid with a bitter taste, a peculiar aromatic smell, and a specific gravity of 1·1313. It contains about 30 per cent. of solid matter when dried at the room temperature.

The acid reaction is believed to be due to formic acid, and the smell to volatile substances, but neither of these have any connection with the poisonous properties of the venom.

The preparation of venom in quantity was carried out by Langer as follows: Several thousand fresh stings with their venom-sacs were placed in 96 per cent. alcohol, which was in due course ed off, when the stings were dried at 40° C., then pulverized extracted with water. The resulting extract, which, when ed, was a clear yellowish-brown fluid, was then precipitated 96 per cent. alcohol. The precipitate, after washing with hol and ether, was dissolved either in ordinary water or in the acidulated slightly with acetic acid. From this solution ger obtained an albumin-free active body after repeatedly ipitating with a few drops of concentrated ammonia and again lving as above. The active principle is, therefore, not minous, and is thought to be an organic base, the nature of h, however, is not known. This poison is destroyed or its vity lessened by oxidizing agents, such as potassium perman- ite, and also by ferments, such as pepsin and rennin.

bcutaneously injected, the venom produces great local irrita- , but heating to 100° C. for fifteen minutes destroys this t.

travenous injections into dogs produce convulsions, trismus, agmus, emprosthotonos, and death from respiratory failure. action is believed by some authors to be due to a neurotoxin, the blood after death is very fluid, and the red corpuscles are royed, indicating a marked hæmolysis, while all the organs pt the spleen show hæmorrhages and hyperæmia; so that the ts may not be due so much to the action on the nervous system o that on the blood. The convulsive effects can be destroyed eating to 100° C. for thirty minutes, when the poison becomes ely narcotic. All effects are annulled by heating to 150° C. ifteen minutes.

he venom, therefore, contains:

Inflammatory poisons, which are thought to come from the gland.

Neurotoxins—

  (1) Convulsive, thought to be derived from the alkaline gland.
  (2) Narcotic, secreted by the acid gland.

Hæmolysins.

ith regard to the last, Morgenroth and Carpi have shown that cithide is formed which is 200 to 500 times more hæmolytic the venom alone. There is, therefore, a similarity between poison and cobra-venom.

e only marked features recorded in human post-mortems are ræmia of the meninges and bloody exudation into the ventricles e brain.

munity.—There appears to be no doubt that bee-keepers attain a considerable amount of immunity against the m.

us, Langer says: Out of 164 bee-keepers, 11 were immune the first; while of the 153 at first sensitive, 126 became more ss immune, and 27 did not. Of the 126 more or less immune persons, 14 said that they were not affected even when several stings were inflicted quickly one after the other.

Bee immunity, however, is only passing, and does not last, and the keepers say that the first sting in the early part of the year may produce a strong effect.

Calmette has immunized a mouse, so that it could resist doses of the venom which would surely have been mortal otherwise.

The Effects of the Venom.—Usually the symptoms are merely local, and limited to pain in the part, redness, and swelling of the skin, and disappear in a few hours. Suppuration is rare, and blood-poisoning very rare, only taking place occasionally if the sting is on the eyes, ears, lips, or in feeble old people.

Slight fever may result in sensitive people, and sometimes general constitutional symptoms, such as nausea, faintness, great weakness, vomiting, precordial distress, difficulty in breathing, coldness of the extremities, with an eruption on the skin like measles, or with wheals. These symptoms may pass on to delirium, unconsciousness, and more rarely death.

Vespa orientalis causes semi-unconsciousness, the face becoming pale and cyanosed, the skin of the extremities cold with a clammy sweat; respiration becomes shallow and sighing; the pulse quick (130 to 140), irregular, and barely perceptible. On recovery from this state of shock, the patient complains of a sensation of tightness in the throat, and œdema may develop in the neck and face, as well as slight fever (100° to 102° F.), all symptoms disappearing in twenty-four hours.

The ordinary bee may at times cause severe symptoms, of which the following is an example: a lady was stung in the forehead, and in four minutes swelling of the eyelids and lips began, which rapidly spread to the arms, and was associated with acute abdominal pain. The hands became rigid in the position of *main en griffe*, and pain and stiffness was felt in the throat, together with difficulty in speaking. There was also vomiting and a sense of chilliness, followed by exhaustion. Recovery was rapid.

Diagnosis.—There is usually no difficulty in this, the history being clear.

Prognosis.—Usually the prognosis is very good; the only dangers are in children and old feeble persons, and in multiple stings.

Treatment.—The usual treatment is by applications of weak solutions of ammonia, which answers well. Carbolic acid (1 in 20 or 1 in 10) is satisfactory if applied immediately after the sting. Potassium permanganate may be tried

Calmette advises a solution of calcium hypochlorate (1 in 60) or eau de Javel (1 in 100). When there is much swelling, apply iced compresses or an ice-bag. When general symptoms develop, strychnine injections may be used.

Formicidæ.

Ants may appear rather insignificant in the Temperate Zone, but in the tropics they are most active, and their bites are very painful Many ants—*e.g.*, *Myrmica* and *Ponera*—have a poison apparatus analogous to that of the bees, which has just been described.

The Venom.—The venom is well known to contain formic acid but there must be more than this in the venoms of the tropica species, though nothing is known on the subject.

The Effects of the Venom.—The symptoms are usually only loca —that is to say, pain, inflammation, and swelling at the site of the bite—but in the case of the large tropical ants general symptoms of faintness, shivering, and temporary paralysis may be produced Indeed, dried red ants made into a paste have already been noted as an arrow-poison.

In Ceylon there is a species of very small ants which infest the beds and bite people while asleep, producing urticarial pomphi.

Treatment.—Apply weak solutions of ammonia, carbolic solution (1 in 20), or camphorated alcohol, to the part. As a preventive measure against the ants infecting beds, spread some powdered camphor in the beds and sheets.

4. Lepidoptera.

Caterpillars of many butterflies are well known to be venomous in the tropics, causing marked skin eruptions, and even a feeling o illness associated with a slight rise of temperature.

Wellman reports that in Angola the most common stinging cater pillar is that of the tiger-moth (Archidæ), called locally ' ochipia —that which burns—which produces an angry eruption associated with much pain. Another belonging to the Limacodidæ, called 'Epuvi,' he describes as causing urticaria. A third, belonging to the Liparidæ, also causes severe local, and at times reflex nervou symptoms. We are acquainted with stinging caterpillars in Ceylon and the Gold Coast, but we have not determined the species. In the former, a bombyx larva living on the *Hibiscus* plant is apt to cause skin irritation. In India, the 'komlah' of the Terai is liable to cause intense irritation if it touches the skin. According to Brooke, the larvæ of *Neæra lepida* and *Adolia* are known to be venomous. Recently Bleyer has described caterpillars belonging to the Bombycidæ of Brazil which possess peculiar stinging organs the venom from which produces locally urticaria and dermatitis, a well as general symptoms, which are best treated by the local appli cation of a 2 per cent. solution of menthol in æther, chloroform and rectified spirits, and by the administration of a mixture con taining liquor ammoniæ acetatis.

Porthesia Chrysorrhœa.—The caterpillar of this brown moth i reported from America (Massachusetts and New Hampshire) a causing a peculiar skin eruption, which Tyzzer says is caused by the penetration into the epidermis of peculiarly modified microscopic hairs called the nettling hairs, which are sharply pointed and barbed. These hairs are specially arranged for penetration, and possess an irritating substance which can be destroyed at 115° C. The other hairs are innocuous. The poison causes necrosis of the cells of the epidermis, together with the formation of small vesicles and inflammation of the corium.

The **Symptoms,** which are generally those of an urticarial dermatitis, but occasionally erysipelatous-like, may be divided into two groups: (1) *severe,* due to contact with the caterpillar; (2) *mild,* due to hairs blown into the air and lodging in skin or undergarments. But it must be remembered that some people are very sensitive and others almost immune.

Treatment.—The best treatment is to clear away the hairs with a little alkaline lotion (bicarbonate of soda 2 per cent.), and then to apply an ointment of ichthyol (10 per cent).

5. Diptera.

The classification of the Diptera is given in Chapter XIX., to which reference should be made.

Culicidæ.—The irritation of mosquito-bites is most noticed by the new-comer to the tropics, for as years go by a kind of partial immunity is acquired, and the bites are much less noticed. Some people appear to have a partial natural immunity to the bites, but this is uncommon.

Only the female mosquito bites and sucks blood, which is supposed to be required for the nutrition of the eggs. When the female mosquito alights upon the skin, it does not always bite at once, but may move from one part to another, apparently testing the different parts of the skin by its labellæ.*

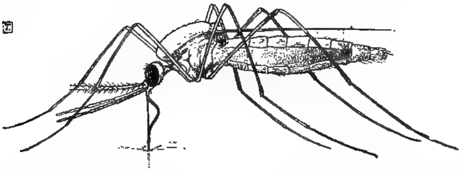


FIG. 25.—AN ANOPHELINE MOSQUITO (A. MACULIPENNIS MEIGEN) IN THE ACT OF BITING.

(After Nuttall and Shipley, *Journal of Hygiene.*)

Note that the proboscis does not enter the wound, and that it is bent convex posteriorly. Note the distension of the abdomen as seen by the space between the terga and the sterna. In the natural condition this space would be bright red from the blood in the abdomen.

Having selected a given area of skin, it moves the palpi away from the proboscis dorsally, and at the same time rotates the labellæ on their hinge-joints outwards.

The labium is now pressed against the skin, and is bent into the form of a bow, convex posteriorly. An opening in the skin is then made, in which the mandibles and maxillæ work like saws, while the head of the mosquito can be seen rocking from side to side. During this process respiration is going on quietly, but at times, according to Schaudinn, a violent contraction of the abdomen is noticed, which is said to be due to the carbonic acid in the superficial layers of the skin, for he found that when carbon dioxide gas acted upon mosquitoes a like contraction was produced.

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* For the anatomy of the proboscis see Chapter XIX., on the Culicidæ.

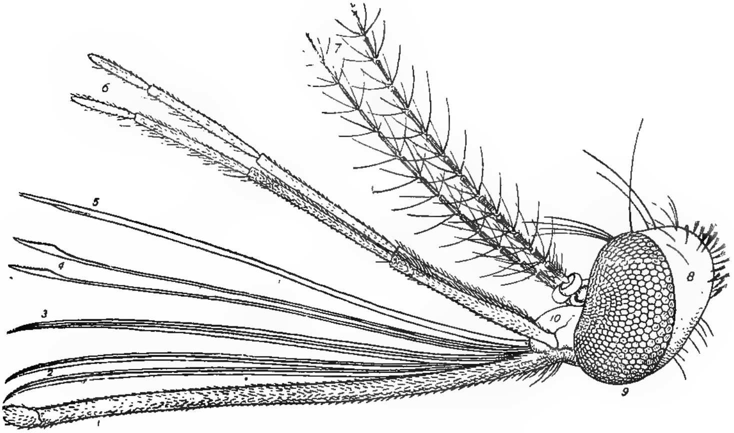

FIG. 26.—HEAD OF ANOPHELES MACULIPENNIS MEIGEN.

(After Nuttall and Shipley, *Journal of Hygiene.*)

1, labium ; 2, maxillæ ; 3, hypopharynx ; 4, mandibles ; 5, labrum ; 6, palpi ; 7, antennæ ; 8, occiput ; 9, eye ; 10, clypeus.

As this process is proceeding, an irritating substance, the chemical nature of which is not known, is injected under the skin, and it is evident that this happens before the mosquito begins to suck blood, for the irritation is present when the insect ceases to bite before drawing up the blood.

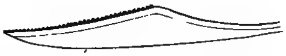

FIG. 27.—ANTERIOR END OF A MANDIBLE.

(After Nuttall and Shipley, *Journal of Hygiene.*)

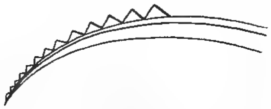

FIG. 28.—ANTERIOR END OF A MAXILLA.

(After Nuttall and Shipley, *Journal of Hygiene.*)

There has been much dispute as to where this substance comes from, but this appears to have been settled by Schaudinn, who triturated the isolated salivary glands in salt solution, which he applied to a wound with negative result. On the other hand, when he applied the isolated œsophageal diverticula to a scratch, he obtained the characteristic irritation and redness. These œsophageal diverticula contain gas-bubbles and bacteria or moulds. The bubbles were shown by Schaudinn to contain carbon dioxide by applying baryta-water to the diverticula, when a precipitate was obtained. The fungi need further investigation, but they or their products appear to be the real cause of the irritation, for when Schaudinn pressed the carbon dioxide out of the sac the signs characteristic of the bite were still produced. It appears probable, therefore, that the powerful abdominal contraction mentioned above expels the gas, bacteria, and fungi from the œsophageal diverticula and the saliva from the salivary glands.

It is possible that the chemical products of the fungi, by causing local irritation, bring more blood into the particular area of skin affected, and thus enable the mosquito to get her supply quickly, for feeding only takes two to three minutes, during which time some mosquitoes will so overfill themselves with blood that it may be ejected *per anum*. The use of the carbonic acid is probably to prevent the coagulation of the blood, which is drawn up the large blood-tube formed by the labrum epipharynx and hypopharynx by the suctorial action of the pump-like pharynx.

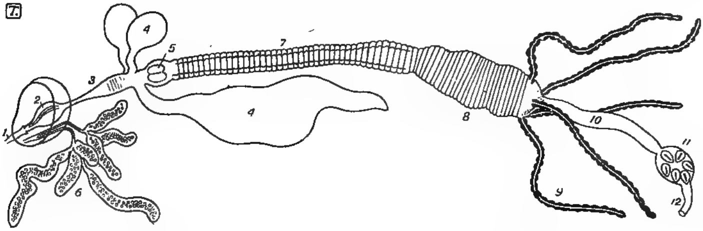

FIG. 29.—THE ALIMENTARY CANAL OF ANOPHELES MACULIPENNIS MEIGEN.

(After Nuttall and Shipley, *Journal of Hygiene.*)

1, Mouth and buccal cavity; 2, pharynx; 3, œsophagus; 4, dorsal and ventral œsophageal diverticula; 5, proventriculus; 6, salivary glands; 7, narrow portion of ventriculus; 8, so-called stomach; 9, malpighian tubules; 10, intestine; 11, rectum; 12, anus.

Symptoms.—Shortly after a mosquito has bitten a person, a sensation of itching is experienced in the affected part, which on examination is seen to be inflamed and reddish, while a wheal not unusually develops, especially in persons new to the tropics. Sometimes a papule or even a nodule may form on the site of the bite, while more rarely scratching leads to secondary infection and the formation of boils, lymphangitis, or lymphadenitis.

Treatment.—The itching may be relieved by dilute solutions of ammonia (Scrubb's Ammonia is a favourite remedy), or by a 5 per cent. solution of carbolic acid, or 1 per cent. alcoholic lotion of menthol. Inflamed bites may be cleaned with 1 in 40 carbolic lotion, and afterwards dressed with boracic ointment. Local septic poisoning should be treated by boracic or carbolic fomentations, while boils and abscesses must be opened.

Prophylaxis.—The prevention of mosquito-bites will be discussed in the chapter on Malaria.

Other Diptera.—Numerous flies other than the Culicidæ cause irritation by their bites, as do fleas, but the nature of the venom not being well known, they will be considered together in Chapters XIX., XX., XXI.

6. Coleoptera.

Beetles and their larvæ are capable of inflicting severe bites or wounds by means of stiff hairs. *Silvanus surinamensis* L., the saw-toothed grain-beetle, is said to bite people. According to Brooke, *Mylabris cichorii* in India, *Lytta villata* in America, *Lytta ruficeps* in Chili, and a species of Cantharis in Senegal, are all venomous. Wellman describes the larva of a beetle, which the natives of Angola call 'ochisia,' which means 'to be left alone,' whose bristles will even penetrate the skin of the sole of the foot, causing pain, inflammation, and even sloughing, when trodden upon.

MOLLUSCA.

A venomous snail of unknown genus and species is described in the Solomon Islands. These snails possess radulæ provided with pointed tubular teeth, armed anteriorly with a barb. These teeth are connected with a poison gland, and are capable of injuring men and producing severe wounds.

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CHAPTER IX

TROPICAL INTOXICATIONS (*continued*)—VENOMOUS ANIMALS

Pisces—Classification—Poison by bite—Poison by stings—Amphibia.

PISCES.

All over the world, but especially in tropical seas, there are fish which for purposes of defence secrete poisonous fluids from special glands. These fish have been but little studied, and still less is known about the nature of their venom and its physiological action. A great deal, however, is known by residents in the tropics about wounds inflicted by these fish, and the doctor practising therein is bound sooner or later to come across not merely persons who know a good deal in a general way about the subject, but those who either are suffering or have suffered from the poisoning. It is therefore necessary that the tropical practitioner should have some knowledge of venomous fish.

The subject might be studied by classifying the fish zoologically, and then taking them seriatim and describing their poison and its effects; but though a zoological list will be given, this does not seem so satisfactory as to follow Bottard in his special classification based on the manner in which the fish inflicts the poison.

Venomous fish may be classified into:—

Class I. Fish which poison by their bite.

Class II. Fish which poison by barbs (spines) connected with special glands.

Class III. Fish which poison by a secretion prepared by the skin glands. This class is illustrated by the lamprey, which is only known to produce poisoning when eaten.

It will be understood from the above classification that venomous fish are to be distinguished from poisonous fish—*i.e.*, from fish which cause symptoms of poisoning when their flesh is eaten—for the flesh of venomous fish can be eaten with impunity. The poisonous fish and their effects have been briefly described in Chapter VII. under the heading Poisonous Food.

During the spawning season the quantity and the virulence of the poison of venomous fish generally increase, and, indeed, some genera—*e.g.*, Cottus—are only venomous at that time. Poisonous glands, being protective, occur more commonly in weak and small rather than in large fish, hence they are more frequent in bony than in cartilaginous fish, which latter are usually of large size. Venomous fish are often conspicuous by form or colour.

Historical.—The history of our knowledge of venomous fish has been well written by Faust, who points out that it was Aristotle, the Father of Ichthyology, who first established the fact that fish could produce poisoned wounds, and that after his day information on this subject appears to have been very uncertain, and doubts were cast upon the facts ascertained by him. Modern knowledge began in 1841 by Allman writing a paper on the stinging properties of the lesser weever (*Trachinus vipera*), which, he said with all reservation, was probably due to a poison gland at the base of the opercular valve. Further researches were made by Byerley in 1849, Günther from 1864 to 1881, Corre 1865-81, Gressin 1884, and Savtschenko, who produced his excellent atlas in 1886. It is, however, Bottard, in his thesis on 'Les Poissons Vénimeux' in 1889, who first gave a clear account of these fish, and he has been followed by Coutière in 1899, Briot in 1902-04, and Evans in 1907. The nature of the poison or poisons, and its or their physiological effects, require still considerable research.

Effects of the Poison.—As far as investigations have gone, it appears as though the venoms of the different fish only varied quantitatively, and not qualitatively. The effects are local and general. The local effects consist in painful sensations, swelling of the part, which may spread over the whole limb, suppuration, and even gangrene. The general symptoms appear to be due in the first instance to the action of the venom on the central nervous system, which shows itself in excitation, and later insensibility and paralysis. An action on cardiac muscle has also been recorded. In man death has been known to occur from wounds of *Synanceia brachio.*

Persons Chiefly Affected.—The persons chiefly affected by the venom are cooks and fishermen, but the latter are well aware of the danger.

Diagnosis.—Diagnosis is to be obtained by the history of the injury.

Prognosis.—This is usually good, but prompt treatment is needed.

Treatment.—The treatment of a poisonous wound due to a fish must be based upon the following principles :

easy to apply proximally a tight bandage with the same precautions as mentioned under Snake-Bite (which see).

2. *Neutralize the Poison locally.*—This should be done by opening the wound and letting it bleed while washing it with 1 per cent. solution of permanganate of potash, or by rubbing in crystals of the same substance, and then applying fomentations and aseptic dressings.

3. *General Treatment.*—The pain must be relieved by hypodermics of morphia, and nervous symptoms by bromides; syncopal attacks by stimulants and hypodermics of strychnine; failure of respiration by artificial respiration.

Zoological Classification.

The venomous fish may be classified as follows:

Subclass I. Elasmobranchii.
Order 3. Selachii.
Suborder 3. Raii.
Family Myliobatidæ.
Myliobatis aquila L.
Aëtobatis narinari Euphrasen.
Family Trygonidæ.
Trygon pastinaca Cuvier and other species

Subclass V. Teleostei.
Grade A. Physostomi.
Suborder 2. Cyprini-siluriformes (Ostariophysi).
Family Siluridæ.
Plotosus arab Forsk.
Saccobranchus fossilis Block.
Suborder 4. Anguilliformes (Apodes).
Family Murænidæ.
Muræna helena L.

Grade B. Physoclisti.
Suborder 10. Acanthopterygii.
Division 1. Perciformes.
Family Acanthuridæ.
Acanthurus luridus.

Division 7. Trigliformes (Scleroparei).
Family Triglidæ.
Trigla hirundo L.
Family Scorpænidæ.
Synanceia brachio Cuv. and Val.
,, verrucosa Schnd.
Scorpæna grandicornis Cuv. and Val.
,, diabolus Cuv. and Val.
,, porcus L.
Pterois antennata Bl.
Pelor filamentosum Cuv. and Val.
Family Cottidæ.
Cottus scorpius L.

Division 8. Blenniformes.
Family Trachinidæ.
Trachinus draco L.
,, vipera Cuv. and Val.
,, radiatus Cuv. and Val.
,, araneus Riss.
Family Uranoscopidæ.
Uranoscopus scaber L.
Family Callionymidæ.
Callionymus lyra L.
Family Batrachidæ.
Batrachus tau.
,, grunniens Bloch.
Thalassophryne reticulata Günth.
,, maculosa Günth.

Addendum.—Serranus outabili (Cuv. and Val.) and Holocanthus imperato (Bl.) are looked upon as possibly poisonous, but there is no definite evidence The Siluridæ are believed to be poisonous, because some of them possess sac like organs opening into the axillæ of the pectoral fins, on which there ar powerful spines.

Geographical Distribution.

The geographical distribution of venomous fish is in temperate and tropica seas:

Teleostomi.

Plotosus arab ..	.. Indian Ocean.
Muræna helena ..	.. Mediterranean.
Acanthurus luridus	.. Tropical Atlantic.
Trigla hirundo ..	.. English Channel.
Synanceia brachio	.. Tropical Pacific.
,, verrucosa	.. Indian Ocean.
Scorpæna grandicornis	.. Waters of the Antilles.
,, diabolus	.. Indian Ocean and Tropical Pacific.
,, porcus	.. Mediterranean.
Pterois antennata	.. Seas of the Indies and Equatorial Pacific.
Pelor filamentosum	.. Waters of l'Isle-de-France.
Cottus scorpius ..	.. Seas of Europe, Asia, and North America.
Trachinidæ ..	.. Waters of Europe.
Uranoscopus scaber	.. Mediterranean.
Callionymus lyra	.. Waters of France.
Batrachidæ ..	.. Waters of Tropical America and India.

Leaving, however, the zoological classification, we will consider the venomous fish according to Bottard's classification, excluding Class III.

CLASS I.

Fish which Poison by their Bite.

The type of this class is the genus *Muræna*, all of which possess powerful teeth capable of inflicting severe bites. According to Cal-poison, and possesses three or four strong conical teeth curved with an anterior convexity. These teeth are not grooved or channelled, but are easily moved and erected, and are enclosed in a sheath formed by the mucosa of the palate. The poison collects between the teeth, and simply flows down them into the wound.

The venom has not been studied, except so far as to show that it has some digestive action. The effect on man is not certainly known, but is supposed to lead to syncope.

Another fish, the bite of which is much dreaded, is *Tetrodon fluviatilis*, which is found in the waters of Indo-China, and frequently attacks the natives, especially children.

CLASS II.

Fish which Poison by Means of Stings associated with Poison Glands.

Bottard classifies the poison apparatus of this class into three groups :—

1. Apparatus entirely closed, and therefore before the poison can escape a membrane must be ruptured :

Synanceia brachio.
,, verrucosa.
Plotosus arab.

Apparatus partially closed :

Thalassophryne reticulata.
,, maculosa.

3. Apparatus in more or less direct communication with the exterior :

Trachinus vipera.
,, draco.
,, radiatus.
,, araneus.
Cottus scorpius.
,, bubalis.
,, gobio.
Callionymus lyra.
Scorpæna porcus.
,, scrofa.
Pterois antennata.
Pelor filamentosum.
Acanthurus luridus.
Uranoscopus scaber.
Trigla hirundo.

The poison glands are generally placed at the base of the dorsal or anal fins, or under spines on the operculum. The gland communicates with one or more rays of the fins. The barbs may be—

1. Grooved, but having the groove converted into a canal by a membrane, which must be ruptured for the poison to escape.
2. Canalized by channels which lead to apertures near its tip.

This arrangement of the rays agrees with the types of poison apparatus mentioned above.

Section 1.—Poison Apparatus entirely closed.

The apparatus is connected with the dorsal fin, and is passively defensive—that is to say, the fish cannot eject the poison unless the barb is broken.

EXAMPLES.—*Synanceia* (*brachio* and many other species); *Plotosus arab.*

Synanceia (*brachio and many other species*).—This fish, called 'rapau de mer' in Réunion, 'laffé' in Mauritius, 'ikan Satan' in Java, and 'nohu' in Tahiti, is distributed through the waters of the Indies, Cochin China, New Caledonia, and the Pacific Ocean.

Its poison apparatus is connected with the dorsal fin, which has thirteen barbs, each of which is supplied with two poison reservoirs, to which belong ten or twelve tubular glands. It cannot eject the poison itself, but if trodden upon by the naked foot, the barb enter the skin, and the poison is pressed mechanically into th wound. The venom is limpid, bluish, and slightly acid. Th symptoms are severe pain, spreading up the limb. The suffere becomes violent, throwing himself from side to side, and eve asking to have his foot cut off. Sometimes syncope and deat may take place. In other cases abscesses and symptoms of blood poisoning may be noted. The skin surrounding the wound become bluish, and may slough, in which case repair takes a very long tim

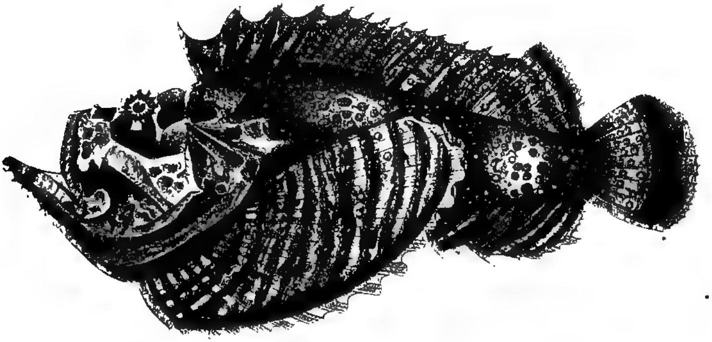

FIG. 30.—SYNANCEIA VERRUCOSA SCHNEIDER.
(From Savtschenko's 'Atlas of Poisonous Fish.')

Saccobranchus fossilis.—This fish is found in the waters of India and Ceylon, and wounds caused by its pectoral fins are much dreaded by the natives, as they produce severe inflammation and even tetanic symptoms.

Section 2.—Poison Apparatus Partially Closed.

The types of this section are *Thalassophryne reticulata* Günther, which is found near Panama, and *T. maculosa* Günther, which is chiefly found in the Gulf of Bahia (Brazil).

In these fish the poison apparatus is double, there being hollow barbs on the gill covers and on the back close behind the head. The barb on the gill cover, which is bent somewhat upwards, is conical in shape and pierced by a central canal, which is connected with a poison reservoir situated at the base of the barb. The cells lining this sac are probably those which secrete the poison. The venom, therefore, is capable of flowing along this canal without being forced by muscular exertion. The barbs on the dorsum of the fish consist of two spines pierced, as in the case of the opercular spine, by canals which communicate with poison reservoirs. When the barbs are erected, the poison flows out of the peripheral openings of the central canals, and thus can enter any wound caused by them. The nature of the venom and its physiological action are not known, but it is supposed that it will be like *Synanceia* and *Trachinus*, though there is no ground for this supposition.

The poison apparatus of *Batrachus tau* of the waters of North America and *B. grunniens* of those of the Antilles are said to be identical (Calmette) with that just described for *Thalassophryne*.

Section 3.—Poison Apparatus in more or less Direct Communication with the Exterior.

This section contains a number of fish, the best studied of which is *Trachinus draco*.

Trachinus draco.—This fish possesses two sets of poison apparatus, the one a barb on the operculum, and the other connected with the dorsal fin. The barb on the operculum possesses a groove which is converted into a canal by a fine membrane, which leaves an opening near the point of the spine. This barb, which is slightly erectile, pierces the operculum. At its base lies the poison gland, partly covered by an adductor muscle, which helps to press the poison into the canal and to erect the spine. When the barb enters the flesh of another animal, the above-mentioned membrane is stripped off and the poison enters the wound.

The dorsal apparatus consists of from five to seven spines joined together by a membrane, which is adherent almost to their tips. Each barb has a deep double channel, the two grooves of which join towards the base of the spine and form a conical space, of which the walls are covered with cells which secrete the poison.

The first symptoms are very severe pain of a burning or lancinating character. The part then tingles and becomes painfully numb, and this may spread along the limb, and appears to travel along the nerves, though the joints are particularly tender. This is followed by palpitation, fever, delirium, vomiting, and syncope. The area affected becomes swollen and inflamed, and if neglected may suppurate or even turn to gangrene. The symptoms may last from two to three hours to several days.

The venom has been studied by Günther, Gressin, Bottard, Briot, and Phisalix. It has also been studied by Evans, who, after washing the fish, collected it by means of an aseptic hypodermic syringe, then dried it *in vacuo*, reduced it to a fine powder, and finally dissolved it in normal saline or in water. He collected the poison from about 2,000 fish. The venom is clear, transparent, and very slightly acid. Hypodermically injected, it causes mortification and local paresis, necrosis, and hæmorrhage. Intravenously injected, it causes failure of the heart and respiratory paralysis, associated with first a rise in the blood-pressure, which is followed later by a marked fall. It also appears to have a hæmolytic effect, which is supposed to be due to its amboceptors uniting with endocomplements (lecithin) in the red cell. It will thus be seen that the poison in some respects resembles snake-venom. The venom is lethal to fish, frogs, and mammals. Thus, 0·015 gramme of dried venom killed a frog, and 0·02 gramme a mouse.

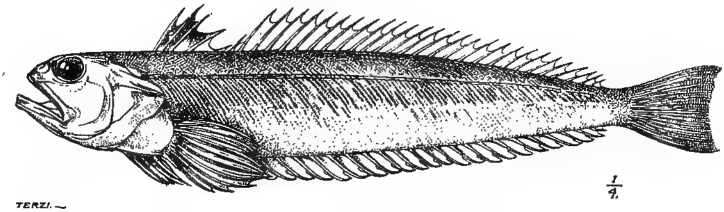

FIG. 31.—TRACHINUS DRACO LINNÆUS.

According to Briot, who has succeeded in immunizing rabbits, the venom contains a ferment capable of digesting proteid.

Trachinus radiatus.—Pohl has studied the poison of this fish, and finds that it stops the heart in diastole. The effect of applying the poison to the heart of the frog is to first produce strong contractions, which gradually become weaker and weaker, until they cease and the heart stands still in diastole. The poison has, however, no effect on skeletal muscle.

Cottus.—The genus *Cottus*, widespread in the Northern Hemi-

Callionymus.—In *Callionymus* the operculum terminates in three conical spines like a trident, and in addition possesses another spine directed upwards, and these are supplied in the spawning season with a small quantity of venom from the gill membrane, which, according to Bottard, has little effect on man.

Scorpæna scropha.—In this fish the poison apparatus is said to exist not merely in the dorsal fin, but also in the operculum.

In the dorsal fin, the first three rays, which project about one-third of their length beyond the membrane of the fin, are grooved posteriorly by three channels, which are converted into canals by a fine membrane, and communicate with the poison gland.

On the operculum there are three small spines, of which the longest alone is connected with a poison gland.

When handled incautiously, a poisoned wound may result from one of these poison spines entering the skin. The action of the poison has been studied by Pohl, Brunton, and Briot. Brunton describes the effects of the poison as being exactly the same as that of *Trachinus draco*, and Pohl thinks that the poison acts on the heart in the same manner as he describes for *Trachinus.*

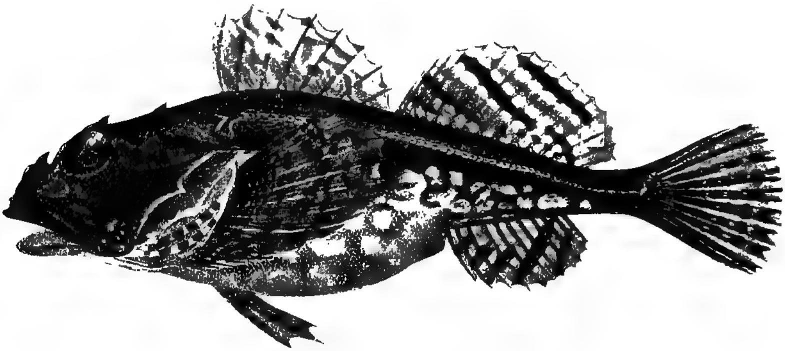

Fig. 32.—Cottus scorpius Linnæus.

(From Savtschenko's 'Atlas of Poisonous Fish.')

On the other hand, Briot thinks that it is quite different from *Trachinus*, and that the effects produced are by secondary infection of the mechanical wound caused by the spines. Brunton's description of the symptoms in man might possibly be due to *Trachinus* only, as he does not mention specifically whether it was *Trachinus* or *Scorpæna* which affected the person. His experiments on animals with both fish appear, however, to have caused the same symptoms. He pressed the spines of the poison organs against the hind-limb of a guinea-pig or a rat. In a few minutes the animal began to suffer pain and twitching in the injured limb, followed by tremors and convulsions (if disturbed), and later by death from collapse.

The description which he gives of the symptoms in human beings for either *Scorpæna* or *Trachinus* is given below, but reference to his original paper will, we think, convince the reader that he is really dealing with a *Trachinus* sting.

The symptoms of an attack may be described thus :

A sharp prick is felt as the spine enters the skin, and this is followed in a few minutes by burning and itching, which shortly become stabbing pains, increasing in violence and passing up the limb. The sufferer now lies down and writhes and cries in agony, while sweat breaks out on his brow, and flashes of light pass in front of his eyes. He begins to feel a sensation of suffocation, and puts his hand to his throat and heart, while the pulse is felt to be intermittent. Presently he loses sight of the bystanders, and in a little becomes delirious, crying out and suffering from convulsions. This condition may lead to collapse and death, or, after lasting several hours, may gradually subside ; but the convalescence is slow, and the patient may take several months to recover.

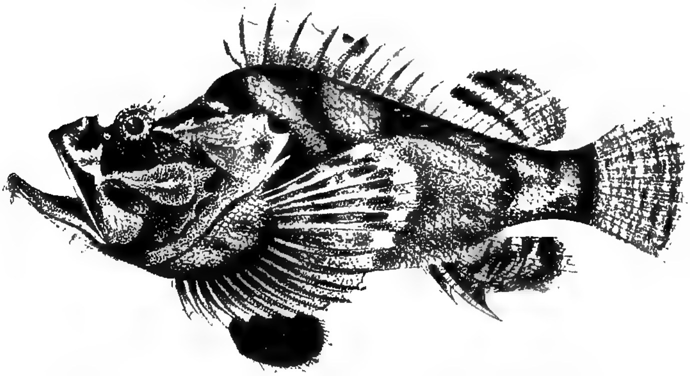

FIG. 33.—SCORPÆNA DIABOLUS CUVIER AND VALENTINE.
(From Savtschenko's 'Atlas of Poisonous Fish.')

The local conditions show at first merely the prick of the spine, but the aperture may be pigmented by the covering membrane already alluded to. The puncture does not bleed, but the skin around for about ½ inch is whiter than usual, and outside this redness appears, but soon all the surrounding skin is red, turning as time passes darker and darker, till it becomes black and œdematous. The prick now discharges fluid. In a day or so the affected area sloughs and separates, leaving a deep wound. Sometimes a spread-

Pelor filamentosum.—In this fish the poison apparatus is connected with the dorsal fin, and resembles that of *Pterois* and *Scorpæna.* With regard to *Pelor japonicum* Cu. and Val., Scheube says that he knew of a case in which a sting on the thumb resulted in phlegmonous and gangrenous symptoms so severe that the arm had to be amputated.

Acanthurus luridus.—*Acanthurus luridus* possesses a poison apparatus connected with the dorsal and anal fins like that of *Scorpæna.*

Elasmobranchii.—Associated with the poisonous fish of the *Teleostei* must be placed those of the *Elasmobranchii*, of which the sting rays (Trygonidæ) and eagle rays (Myliobatidæ) alone produce toxic symptoms by blows with the tail, which carries a spine. These Rays are found all over the world, and we have received information as to their effects from persons who have been in British Guiana, in Australia, and in Ceylon, in which island stings are well known on the west coast, particularly about Dutch Bay.

Dr. Crevaux has studied Rays from the Orinoco, and has shown that their barbs are canalized and the canals connected with poison reservoirs. This poison is said to be so severe as to be able to kill a man in forty-eight hours. The symptoms of *Aëtobatis narinari*, called the Bishop ray, and of *Trygon pastinaca* (from Japan), are violent pain, a tendency to syncope, with locally a rapidly forming swelling, which soon becomes the seat of a violent inflammation and even at times gangrene. The symptoms of the sting, as observed by us in Ceylon, are local pain and swelling. The general symptoms are not severe. *Trygon sephen* and *T. walga* Müll. and Hen. are known in Indian waters.

A large number of these *Elasmobranchii* have not got special poison glands, and the venom must come from the ordinary skin glands.

Amphibia.

Toads and salamanders have been celebrated for ages as venomous animals, the poison being found in their parotid glands and skin. In toads Faust has shown that there are two poisons—(1) an acid, bufotalin, and (2) a neutral body, bufonin, the former being the more active. It is, as a rule, scarcely toxic to man, only irritating the mucous membranes, especially the conjunctiva ; but to small animals it is toxic.

In salamanders Zalesky and Faust have found two bodies, one an inorganic base—salamandarin—and another an alkaloid—salamandaridin ; but this poison and the digitalis-like poison of Bert and Dulartre in frogs are not of sufficient practical interest to concern us here.

According to Vulpian and Caparelli, *Triton cristatus* (Laur) gives a creamy secretion from the glands of the skin at times which is poisonous to many animals, but the chemical nature of which is not known.

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CHAPTER X

TROPICAL INTOXICATIONS (*continued*)—REPTILIA

Reptilia : Ophidismus.—Historical—Classification—The act of striking—The venom—Entry of the venom into the body—Minimum lethal dose—Effects of the venom—Excretion of the poison—Immunity—Diagnosis—Prognosis—Treatment—Prophylaxis.—*Lacertilia.*—*Mammalia.*

REPTILIA.

THE Reptilia include two groups which are of interest to medical men in the tropics—viz., the Ophidia and the Lacertilia ; but the former is infinitely more important, as it includes the venomous snakes.

Snake poisoning is called 'ophidismus.'

OPHIDISMUS.

Ophidismus, or snake poisoning, is the most important branch of animal poisons, because not merely do serious and even fatal results follow snake-bite, but the number of people who die from this cause in India is by no means small, being, it is said, about 20,000 per annum.

Historical.

The history of the study of snake-bites and their effects may be divided into three periods :

1. Period of ancient theories.
2. Period of one venom.
3. Period of more than one venom.

1. **Period of Ancient Theories.**—The ancients were acquainted with a number of snakes, which they described under the terms *Echis* and *Colubra*, but it is not known definitely to what species these referred. *Echidna* was a term used to denote the female viper.

They were acquainted with the main symptoms of a snake-bite, and had many remedies, including the tying of a ligature around the part followed by cupping after scarification, and the administration of wine and theriac, the last-mentioned being a celebrated remedy which, among other substances, contained the burnt body of the viper. Celsus recommends the sucking of the wound, but only if there are no ulcers on the gums, palate, and other parts of the mouth.

2. **Period of One Venom.**—In 1664 Redi studied the effects of viper-bites by experiments on animals, and Morse Charas, in 1669, noted the important fact that the blood of animals bitten by vipers was coagulated, and came to the conclusion that the symptoms and death were due to this coagulation.

In 1767 Abbé Felix Fontana made a number of observations on animals bitten by vipers, and in 1796 Russell published an account of his experiments on Indian snakes. In 1821 Davy gave an account of the effects on animals of the bites of three Ceylon snakes.

In 1843 Prince Lucien Bonaparte published his important discovery that the venom of the adder contained an active substance, which he called viperine, or echidnine, capable of being precipitated by alcohol.

In 1845 Brainard showed that if an animal dies at once after the bite of a rattlesnake the blood will be found to be clotted, but if it lives for some time it will be fluid.

In 1860 Weir Mitchell laid the foundations of modern investigations into snake-venom in his classical paper on the poison of *Crotalus durissus*.

In 1867 Sir Joseph Fayrer began his work on Indian snakes, which resulted in the publication of his magnificent altas on the Thanatophidia of India in 1872, and several papers by himself and Sir Lauder Brunton in 1873-75.

About the same time Vincent Edwards published some valuable remarks on snake poisons and their antidotes.

In 1883 Wall wrote a most excellent little book on the colubrine and viperine snakes of India.

In 1886 appeared a most masterly paper by Weir Mitchell and Reichert, in which they state that the active principles are globulins and peptones (proteoses). These researches indicating a proteid nature for the venom were confirmed by Wolfenden and Karlbach, and did away with Gautier and Blyth's ideas as to their alkaloidal nature.

In 1892 Martin alone and with Smith studied the venom of Australian snakes (*Hoplocephalus* and *Pseudechis*), and concluded that the venom contained three proteids—an albumin and two proteoses (proto and hetero), the latter, however, being alone virulent.

In the meanwhile observers had not been backward in making attempts to find the physiological antidote suggested by Weir Mitchell and Reichert, for in 1887 Sewall showed that by repeated injections of the venom of *Crotalus*, pigeons could be gradually rendered resistant against strong doses of that poison; and a little later Reichert obtained the same result with regard to the venom of the French viper. In 1892 Calmette published the first of his celebrated series of investigations, showing that successive inoculations of heated venom produced in animals a certain degree of resistance to quantities of the poison otherwise surely fatal. Calmette worked largely with the cobra, and produced in rabbits and guinea-pigs a true immunity. He further concluded that animals vaccinated against the cobra also withstood with impunity mortal doses of the venom of the viper and other snakes (*Bungarus*, *Cerastes*, *Naja haje*, and *Pseudechis*).

Phisalix and Bertrand also studied the question of obtaining an immunity against the bite of the viper. Fraser of Edinburgh in 1895 confirmed these results of Calmette. Since then there has not been the slightest doubt that Calmette's serum is of the greatest value in certain cases, especially against cobra venom.

In 1881 permanganate of potash was recommended as an antidote by Professor de Lacerda, of Rio de Janeiro, and by Badaloni in Italy in 1882-84, and lately this remedy has again been strongly recommended by Rogers, of Calcutta, and there appears to be no doubt as to its efficiency; but the

Period of more than One Venom.—The third period, extending up to the present, is that in which there is the conception that there are at least two definitely separate types of venom, one of which may be called the colubrine type, having as its example *Naja tripudians;* and the other the viperine type, which may be exemplified by the *Vipera russellii.* In addition, however, there are venoms which show characters belonging to both types.

Weir Mitchell alone and with Reichert indicated that there was a difference between viperine and colubrine poisons; and C. J. Martin, working on *Pseudechis,* a colubrine snake, discovered the intravascular clotting, and suggested that the sudden death caused by *Vipera russellii* might be due to this cause, which hypothesis Lamb and Hanna confirmed.

The difference in the working of these two classes of venoms is still further accentuated by the researches of Rogers, and later by those of Lamb, which clearly prove that Calmette's antivenene will neutralize the colubrine, but not the viperine, venom.

In 1902 a most valuable paper appeared, by Flexner and Noguchi, showing that, in addition to the neurotropic principles, the venom contained agglutinins for the erythrocytes and for the leucocytes which were probably identical, and lysins for erythrocytes and leucocytes which were separate.

They also pointed out that venom contained hæmorrhagins, and lessened the bactericidal powers of the blood. They showed that antivenene neutralizes venom by removing the hæmolytic and antibacteriolytic actions. These results have been confirmed and extended by Kyes, Sachs, Lamb, and others.

The position at the present time is that, though snake venom is extremely complex, still, three kinds of venom may be recognized: colubrine type, viperine type, and mixed type. In this last both colubrine and viperine types are represented, but one is predominant. It is probable that the main action of both types is on the nervous system, but that other principles in the venom may mask this important action.

With regard to treatment, there is no doubt as to the value of Calmette's serum in cobra-poisoning, and Lamb's serum in Cobra and *Vipera russellii* poisoning, though the old method of ligature and incision, together with the application of permanganate of potash, is still the most practically useful method of treatment.

Classification.

The order Ophidia includes a large number of families, of which only two are of importance to the tropical practitioner—viz., Colubridæ and Viperidæ.

COLUBRIDÆ.

The family of the Colubridæ is said to contain nine-tenths of the whole of the species belonging to the Ophidia, and, roughly speaking, any reptile which would usually be called a snake, other than pythons and vipers, belongs to this order.

The Colubridæ are divided in works on snake poisons into the non-venomous and the venomous, and the latter are joined with the vipers to form a subclass of the order Ophidia called Thanatophidia, or poisonous snakes; but this classification is by no means satisfactory, as will presently be shown.

The usual classification of the Colubridæ is into three series.

1. **Aglypha—Poisonous Colubridæ possessing solid ungrooved teeth.**—The Aglypha are usually stated to be non-poisonous, but the observations of Phisalix and Bertrand on *Tropidonotus* (sp. ?), and Alcock and Rogers on *Zamenis mucosus* and *Tropidonotus piscator,* prove that the saliva of these species is poisonous to rats,

mice, and guinea-pigs. Thus hypodermic injections of the saliva of the two last-named snakes will cause convulsions and death from failure of respiration in rats and mice.

Therefore the saliva, though it may not be known to have affected even a child, must be looked upon as poisonous, and the Aglypha must be grouped with the other Colubridæ and the Viperidæ under the head Thanatophidia.

The Aglypha are divided into three sub-families: Acrochordinæ, Colubrinæ (rat-snakes), and Dasypeltinæ (African egg-eating snakes).

Some of the important species are *Tropidonotus natrix,* the common British snake, and *Coronella austriaca,* a rare snake found in South England.

Tropidonotus fasciatus is the North American water moccasin, *Zamenis mucosus* the Indian rat-snake, and *Dasypeltis scabra* is the African egg-eating snake.

2. **Opisthoglypha—Poisonous Colubridæ with one or more of the hinder teeth of the upper jaw grooved.**—Early last century there was a great controversy as to whether these snakes were poisonous or not, and it is generally stated nowadays that, though poisonous, their venom is weak, and that the position of the poison-fangs at the back of the mouth prevents the bite from hurting man. Quelch has, however, recorded cases in which bites on the fingers from *Erythrolamprus æsculapii* L. and *Xenodon severus* have caused severe inflammation.

The following list is given by Faust as being known to be poisonous to animals: *Cœlopeltis monspessulana* Herm, *Trimorphodon biscutatus* D. and B., *Tarbophis savignyi* Descr., *Dryophis prasinus* Russl., and *Leptodira annulata* L.

The Opisthoglypha are divided into three sub-families:

(1) *Dipsadomorphinæ—Opisthoglyphida with well-developed mouth, and nostrils situated at the side of the head.*—They include the Indian tree-snakes.

(2) *Elachistodontinæ—Opisthoglyphida with rudimentary teeth on the palatine aud pterygoid bones.*—Their venom is said to be so weak and their poison-fangs so unfavourably situated that they are not to be considered as dangerous to man. They include the Indian egg-eating snakes.

(3) *Homalopsinæ—Opisthoglyphida with nostrils valvular and situated on the upper part of the snout.*—They are all water-snakes.

3. **Proteroglypha—Poisonous Colubridæ with the front teeth in the upper jaw well developed to form fangs, and grooved anteriorly. The bases of these fangs are connected with ducts which lead from**

hen excited, it expands the skin behind the head by throwing utwards the cervical ribs.

Buddhists regard these snakes with reverence, because one with even heads is said to have placed its expanded hoods over Buddha's ead, and thus to have protected him from the glare of the mid-ay sun.

Naja tripudians Merr., the cobra with one spot, or a pair of pectacles on its hood, is common in India and Ceylon. *N. bungarus* chlegel., the king cobra, or hamadryad, is not so common, but is eared because of its size, and because it is said to attack people. *N. haje* L. is Cleopatra's asp, and is well known as a resident of Egypt and North Africa. *N. regalis* Schl. is found on the Gold Coast. *N. nigricollis* Reinh. is found on the Gold Coast and in Sierra Leone.

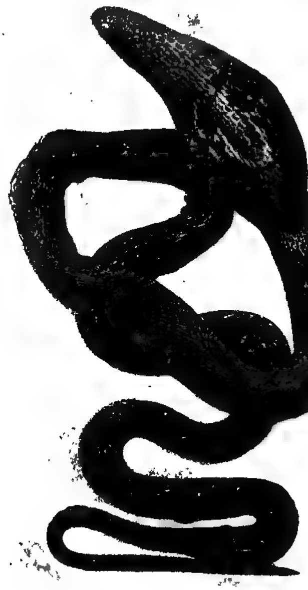

FIG. 34.—NAJA TRIPUDIANS MERREM (THE COBRA).

The kraits are also included in this family, and are *Bungarus candidus* L., the true krait, and *B. fasciatus* Schn., the banded krait, with yellow and black bands, both of which are common in India, while *B. ceylonicus* Gthr. is the carawalla of Ceylon. The Elapinæ are the only poisonous snakes of Australia, and include *Notechis scutatus* Ptrs. and *N. pseudechis*, and *Acanthophis antarcticus* Shaw, the death adder, recognized by the spines on its tail.

Elaps corallinus Wied, the coral snake, with black and red bands separated by narrow rings of a yellow colour, is found in Columbia, British Guiana, Venezuela, and Brazil.

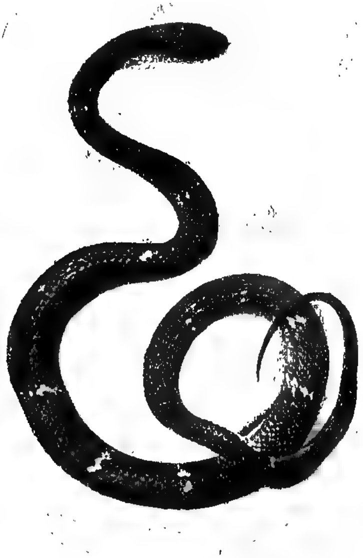

FIG. 35.—BUNGARUS CEYLONICUS GÜNTHER (THE CARAWALLA OF CEYLON).

The *Sepedons* are hooded snakes like cobras (*Sepedon hæmachates* Lacép of South Africa), and are supposed to throw their venom so far that there is a danger of it getting into the eyes of animals and human beings, and causing severe conjunctivitis.

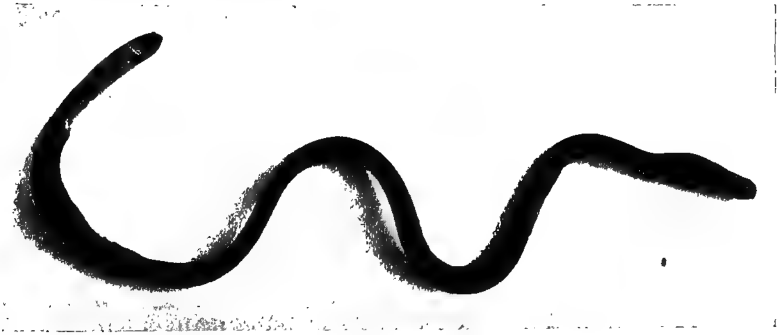

FIG. 36.—HYDRUS PLATURUS LINNAEUS (A SEA-SNAKE). Note the flattened tail.

None of these snakes are found in Europe or America.

Hydrophinæ—Proteroglyphæ living in the sea, and possessing a at tail.—These snakes can be seen swimming in families far out ı the Indian Ocean, but are also found in all Eastern tropical seas. The best-studied species is *Enhydrina valakadien* Boie. Another ɔecies, *Distira semperi* Garm, lives in fresh water in the Philippine slands. It is, of course, dangerous to fishermen.

VIPERIDÆ.

The vipers are characterized by their triangular head and their ubular poison-fangs (hence the name Solenoglypha), which are situted anteriorly in the mouth, and are provided with a wide foramen, iercing the base anteriorly for connection with the duct of the ɔoison gland. They possess a stout body and short tail, and are all ⁄iviparous.

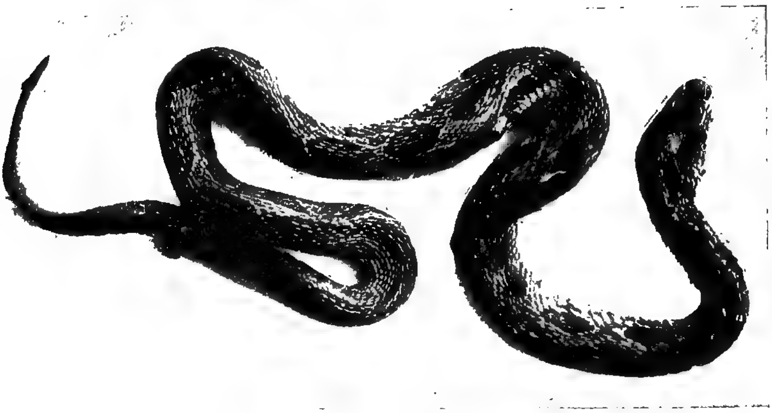

FIG. 37.—VIPERA RUSSELLII SHAW (THE TICOLONGA OF CEYLON).

The vipers are divided into—

Crotalinæ.—Vipers with a deep pit, probably sensory in function, ituated between the nostril and the eye on each side of the head.

Viperinæ.—Vipers without such a pit.

Crotalinæ.—The Crotalinæ include the rattlesnakes, so called because they have a number of horny rings which fit into one another at the end of the tail.

There are two divisions of rattlesnakes in America—*Crotalus* and *Sisturus*—distinguished by the former having many small, and the latter only nine large, scales on the top of the head.

The best-known rattlesnakes are *Crotalus horridus* L., *C. scutulatus* Kenn, of Texas, *C. confluentus* Say, of the Pacific, *C. durissus* L., and *C. cerastes* Hallow.

Other genera are *Ancistrodon*, with *Ancistrodon piscivorus* Lacép, the water moccasin, and *A. contortrix* L., the copper-head ; *Lachesis*, with *Lachesis lanceolatus* Lacép, the celebrated fer-de-lance of Martinique ; *L. anamallensis* Gthr. and *Sisturus*, with *Sisturus ravus* Cope and *S. miliarius* L.

Viperinæ.—The true vipers include : *Vipera berus* L., the adder of England ; *V. russellii* Shaw, the handsome viper of India and Ceylon ; *Bitis arietans* Merr, the puff-adder of the Gold Coast ; *Cerastes cornutus* Forsk, the horned viper of North Africa ; and *Echis carinatus* Schn., the viper of the Pyramids, called ‘ efa.’

The Act of Striking.

The poison is secreted by glands, which are either modified upper labial glands or a pair of glands occupying the sides of the head behind the eyes, and which are the homologues of the parotid gland of other animals. The duct usually begins as a receptacle which runs the whole length of the gland. This receptacle is of importance, as it enables the reptile to store the venom. Into this receptacle the smaller ducts of the gland open, and from it the main duct runs forward just above the line of the lip, to a point below the eye. It is now bent backwards, and ends on a small papilla on the anterior wall of the sheath of mucous membrane, which embraces the base of the fang.

Weir Mitchell describes a sphincter muscle of reddish appearance, and composed of non-striated muscle, on the course of the duct of *Crotalus*, but no such sphincter has been described in the other snakes.

The poison from the duct either runs along a groove on the anterior surface of a long tooth called the fang, or else along a canal formed by the sides of the groove meeting and coalescing by the bending of the developing dentine. The vipers have the longest fangs, measuring nearly 1 inch.

The poison fang projects downwards and backwards in the closed mouth, being firmly attached to the alveolar process, and it is entirely due to the free mobility of the cranial bones one on the other that the fang can be placed in such a position as to be able to enter the skin of the victim.

The act of striking, as described by Weir Mitchell in *Crotalus*, is as follows :

In preparing to strike, the snake first of all throws itself into its well-known characteristic attitude, with the lower part of the body coiled, the tail slightly projecting, and the head raised a few inches.

The tongue now darts backwards and forwards, and the air of expiration, in passing through the narrow glottis, produces the characteristic hissing. The muscles on the convexity of the coils now contract and straighten the snake, so that the head is thrust suddenly upwards, forwards, or downwards as required. The maximum thrust is half of the body-length, the usual one-third ; but the reptile judges this for itself, and sometimes makes mistakes.

The jaws are widely separated, and the head is bent back on the cervical vertebræ, and a muscle called the spheno-pterygoid, which, passing from the basal orbito-sphenoid region backwards, to be inserted into the inner dorsal surface of the pterygoid, contracts, and draws forward the pterygoid, thus pushing upwards the ectopterygoid (transversum), and causing the superior maxillary bone to rotate forward on its lachrymal articulation, and thus to erect the fang. This motion, when it reaches its limit, is checked by ligaments, and now the lachrymal yields a little to the force applied to the maxilla, with the result that the whole muzzle of the snake is elevated, and produces the curious appearance which it has when preparing to strike. The fang now enters the flesh of the victim, and the head of the snake is drawn violently backwards, too much action being prevented by the muscles of the spine. In the meanwhile the spheno-pterygoid, acting from the pterygoid, and together with the external pterygoid, rotates the maxilla and pulls the fang backwards, and so drives it deeply into the flesh.

The lower jaw now closes on the bitten part, and this act squeezes he fluids from all parts of the glands forwards into the duct, and not merely deepens the wound, but injects the venom forcibly into it.

The snake then has to disentangle itself, and in so doing may ose its fang. But this is of no moment, for fangs are shed naturally, and there are a number of tooth-germs in different tages of development ready to take the place of the lost tooth.

Sometimes the fangs have not been properly erected, and therefore only their convex borders touch the skin of the victim, in which case the venom will flow on to the skin, but the fangs will not penetrate.

The Venom.

Collection.—The venom can be collected by making the snake strike a watchglass covered with a thin, tightly stretched piece of ndiarubber sheeting, or by chloroforming the snake and squeezing the poison out of the glands into a vessel.

In order to preserve this venom, it must be quickly dried over calcium chloride or sulphuric acid in a desiccator, when it will keep for years—*e.g.*, Weir Mitchell kept his *Crotalus* venom for twenty-three years, and then found it active.

Physical Characters.—The quantity of the venom obtained depends upon many factors, such as the general condition and size of the snake, whether it has previously ejected venom, and whether it has been long in captivity—a condition in which the secretion diminishes.

An adult cobra in good condition is said by Martin to give from 0·6 c.c. to 1·1 c.c., and this should yield from 200 to 370 milligrammes of solids. Calmette gives 124 milligrammes of liquid venom, yielding 35 milligrammes of dry venom for *Naja haje* L.

The water-snake, *Enhydrina valakadien* Boie, gives only 9·4 to 2·3 milligrammes of dry venom, according to Rogers.

A *Vipera russellii* Shaw gives from 0·6 c.c. to 1·0 c.c. of liquid, which yields 150 to 250 milligrammes of solids.

According to C. J. Martin, *Notechis scutatus* Ptrs. gives 205 milligrammes of liquid, containing 73 milligrammes of solids, *Notechis pseudechis* 160 milligrammes of liquid and 94 milligrammes of solids.

According to Calmette, *Lachesis lanceolatus* Lacép gives 320 milligrammes of liquid venom, containing 127 milligrammes of solids. *Cerastes cornutus* Forsk from Egypt gave 123 milligrammes of liquid and 27 milligrammes of solids, and *Crotalus confluentus* Say gave 370 milligrammes of liquid and 105 milligrammes of solids; while *Crotalus durissus* L., according to Flexner and Noguchi, yields from 309 to 179 milligrammes of dry venom; and *Ancistrodon piscivorus* Lacép from 180 to 125 milligrammes.

The different venoms vary in physical characters, as may be judged by a few descriptions.

Cobra-venom, when fresh, is a transparent, almost colourless fluid, with a syrupy consistence and a disagreeable bitter taste.

When dried, it becomes yellowish-brown, and may be kept for months. It can decompose and become of a dark brown colour, possessing a disagreeable odour.

Crotalus-venom, according to Mitchell, may vary from a pale emerald-green to an orange or straw colour, and when dried resembles dried albumin. It has no taste or smell.

The poison varies in colour, being clear and limpid or pale straw or yellow in colour, which is said to vary with the degree of pigmentation of the snake and the concentration of the venom.

The specific gravity varies from 1030 to 1044 (Weir Mitchell) for *Crotalus*, 1110 for *Cobra*, and 1077 for *Vipera russellii*.

Microscopically, there may be only a few epithelial cells and salivary corpuscles and bacteria, all due to contamination with fluids from the mouth.

Chemical Analysis.—The reaction of pure venom is acid.

The ultimate analysis was made by Armstrong for Sir Joseph Fayrer, and is as follows:

Crude Dried Poison.

Carbon	43·55
Nitrogen	13·43

Alcoholic Extract.

Carbon	45·76
Nitrogen	14·30
Hydrogen	6·60
Sulphur	2·50
Ash	Traces.

These figures merely indicate the presence of proteid in some form, and, as a matter of fact, Armstrong found reactions indicating the presence of albumin; but it must be remembered that Prince Charles Lucien Bonaparte had already shown that a proteid existed in the venom of the viper, and that the toxicity was carried down with this when precipitated, and, further, that Weir Mitchell had corroborated his statements while examining Crotalus-venom.

Weir Mitchell and Reichert went further, and discovered toxalbumins of the nature of globulins (which must be considered to include the more modern proteoses) in venom. They considered these proteids, which they found to be poisonous, to be the true active principles of the venom. In this they have received support from Phisalix and Bertrand, who separated from viper-venom two toxalbumins—echidin, which acts locally; and echitoxin, which acts generally—and also from C. J. Martin and Smith, who showed that the proteoses consisted of proto- and heteroproteose, with perhaps a little deuteroproteose, and that true peptones were absent.

The reader will, therefore, not be surprised to hear that venom gives proteid reactions—*e.g.*, Millon's, the xanthoproteic and the biuret—and that precipitates appear on the addition of picric acid, copper sulphate, and alcohol, and on saturation with sodium chloride, magnesium chloride, or ammonium chloride, and, lastly, that it coagulates on heating.

With regard to heat, it is found that viperine venoms more readily lose their toxicity than colubrine—*e.g.*, 80° to 85° C. will destroy most of the former venoms, while it takes 120° C. to do the same to those of the latter with certainty.

If venom is only heated to the temperature of first coagulation, and then filtered, it will be found that the filtrate still gives a precipitate with alcohol, and is still active, though its virulence is diminished, and that this action is mostly on the nervous system.

The analysis of venom, however, does not stop with toxalbumins, for, as Ewing pointed out long ago, they contain true toxins allied to those produced by bacteria, and recently Faust has separated from the toxalbumins a very poisonous non-nitrogenous substance called *ophiotoxin.*

The knowledge of these toxins is principally due to the work of Flexner and Noguchi on the venoms of *Crotalus durissus*, *Ancistrodon piscivorus*, *A. contortrix*, and *Naja tripudians.*

The work of these investigators, coupled with that of C. J. Martin, Calmette, Lamb, Weir Mitchell, Reichert, Stewart, Rogers, and others, have shown that snake-venoms are very complex liquids containing some, but not in any one venom all, of the following active principles:

1. *Neurotoxins.*
    (1) Acting principally on the respiratory centre.
    (2) Acting principally on the vasomotor centre.
    (3) Acting upon nerve end-plates in striated muscle, particularly on those of the phrenics.
2. *Agglutinins.*
3. *Cytolysins.*
    (*a*) Hæmolysins.
    (*b*) Leucolysins.
    (*c*) Hæmorrhagins.
    (*d*) Other cytolysins.

4. *Antihæmolysins.*
5. *Antibactericidal substances.*
6. *A fibrin ferment.*
7. *An antifibrin ferment.*
8. *A proteolytic ferment.*
9. *A cardiac and vascular tonic.*

Of these principles, the most important are the neurotoxins, the cytolysins, and the fibrin ferment.

The analysis of the venom, according to Martin, may be effected by:

(1) Dialyzing and filtering the venom through a gelatin filter supported in the pores of a Pasteur-Chamberland filter. *Fibrin ferments and hæmorrhagins do not dialyze.*

(2) Heating from 70° to 100° C., when some *neurotoxins* and some *hæmolysins* will not be affected.

(3) Hæmolysins can be separated from neurotoxins by digestion with red blood cells mixed with serum which has previously been heated to 56° C.

Neurotoxins and other cytolysins can be separated by the method of Flexner and Noguchi, which will be described later. It must be clearly understood that the venom of any one snake does not contain all these principles.

1. NEUROTOXINS.—The neurotoxins are the most important active principles of the venom of many snakes, especially the colubrine snakes. They have been studied in *Ancistrodon contortrix* by Flexner and Noguchi, who tested the anchoring power of the various tissues of the body for the principles in venom in the following manner: They took a definite weight of tissue washed in tepid, sterile, normal saline solution, and after triturating it in a sterile mortar, mixed it in test-tubes with a given number of minimal lethal doses (M.L.D.) of the venom. The mixture, after being placed in a thermostat for one hour, was centrifugalized, and the supernatant fluid injected into guinea-pigs. They first took 2 grammes of the organs, and mixed them with three times M.L.D., calculating that after centrifugalizing there should be left at least two M.L.D.

The results were as follows:

Control guinea-pig died in 45 minutes.
Brain-injection guinea-pig died in 19 hours.
Blood-injection guinea-pig died in 3 hours 50 minutes.
Adrenals-injection guinea-pig died in 2 hours 35 minutes.
Spleen-injection guinea-pig died in 2 hours 10 minutes.
Liver-injection guinea-pig died in 1 hour 30 minutes.
Kidney-injection guinea-pig died in 1 hour 55 minutes.
Muscles-injection guinea-pig died in 1 hour 30 minutes.

Next they tried two M.L.D., with the following results:

Brain-injection guinea-pig survived.
Blood-injection guinea-pig died in 28 hours.
Liver-injection guinea-pig died in 19 hours.

From these experiments they conclude that snake-venom contains a neurotoxic principle, which is the chief poison, and which unites in multiple minimal doses with the nerve cells, but that, even if this chief toxic principle be removed, there is still left sufficient hæmolysin to cause death.

This neurotoxic substance has been shown by Rogers in the cobra and the Hydrophidæ to attack the respiratory centre in the medulla, the respirations becoming both fewer in number and less in amplitude minute by minute, until they cease if sufficiently large doses are administered, but when smaller doses are given there is at first a temporary stimulation.

Further, he shows that the neurotoxic substance can paralyze the end-plates of the phrenic nerves in the diaphragm shortly after the failure of the respiratory centre in the medulla.

The blood-pressure does not appear to be affected by the poison, and, in fact, the circulation can be kept going for a long time after cessation of breathing if artificial respiration is resorted to—a fact first shown by Brunton and Fayrer.

On the other hand, with regard to viperine snakes—*e.g.*, *Vipera russellii*, *Bitis arietans*, *Crotalus horridus*, and *Lachesis anamallensis*—Rogers concluded that the neurotoxin acted upon the vasomotor centre in the medulla—a point which was noted by Weir Mitchell and Reichert as a cause of the variation of the blood-pressure in Crotalus poisoning.

There are thus several neurotoxic elements in snake-venom, of which two great groups can at present be provisionally described:

(1) Colubrine neurotoxic element, acting upon the—(1) Respiratory centre in the medulla; (2) the end-plates of the phrenic nerve.

(2) Viperine neurotoxic element, acting upon the vasomotor centre in the medulla.

Kilvington has studied the effects of the venom of *Hoplocephalus curtus* Günther (*Brachyaspis curta* Schleg) on nerve cells, and found that the nerve cells of the central part of the cervical enlargement showed a breaking-up of the Nissl granules into a fine dust-like deposit. The nucleus may become indistinct, but it remains in the centre of the cell. The cells are unequally attacked. Those around the central canal are most severely injured, while the motor cells are little affected. In sudden death no change is noted. He says that the character of the changes are of the same order as those described by Marinesco as toxic degeneration, and are very like those following the fatal dose of abrin. Inflammatory and vascular changes are absent.

As to the cause of this cyctolysis, it would appear from the researches of Flexner and Noguchi that it is probably due to the union of an endocomplement (capable of being neutralized by calcium chloride, and therefore not lecithin) in the nerve cell with an amboceptor in the venom. This neurotoxin, according to Ehrlich's denomination, is neurotropic—*i.e.*, unites only with nerve cells—and monotropic—*i.e.*, has affinities for one tissue only.

These facts have been demonstrated by Flexner and Noguchi in cobra-venom by first treating it with erythrocytes to remove the hæmolysin, and then heating it to destroy the hæmorrhagin, thus leaving only the neurotoxic principle to act on the animal.

They found that after cerebral injection the appearance of the nervous symptoms was almost immediate, while with other methods of injections the development was more gradual.

The first effect of the neurotoxin was irritation (convulsions), and the final paralysis. By cobra-venom, death was caused by respiratory paralysis. Intracerebral injection of a viperine venom like that of *Crotalus*, however, caused but slight symptoms.

They further found that the venoms of *Ancistrodon piscivorus* Lacép and *A. contortrix* L., occupied an intermediate position between the colubrine and viperine venoms, containing both neurotoxins and hæmolysins in considerable quantities. From these experiments it was possible to classify venoms into the three classes given above.

2. AGGLUTININS.—Agglutination of the red cells was first described by Weir Mitchell and Reichert, and that of the leucocytes by Halford and Ralf.

The reaction can be studied by adding a 0·01 per cent. to 10 per cent. solution of dried venom in normal saline to washed corpuscles suspended in normal saline.

The time required for agglutination depends upon the strength of the solution of venom, and the effect upon the corpuscles depends upon whether they come together quickly or slowly. In the former case they are not damaged, while in the latter their shape is considerably altered. Agglutinins are destroyed by heating the venom to 75°-80° C.

The agglutinins for the red cells appear to be the same substances as those for the white, and in both cases they appear to act prior to the cytolysis of the cells.

3. THE CYTOLYSINS—(*a*) *Hæmolysins.*—Fontana many years ago noted that the blood of animals bitten by vipers was fluid, and Weir Mitchell and Reichert described the hæmoglobin dissolving out of the agglutinated red corpuscles, which finally became invisible when treated with Crotalus-venom. Feoktistow showed that a 2 per cent. solution of the venom of *Viper berus* destroyed red corpuscles in eighteen to twenty-four hours. Martin has also demonstrated that the venom of *Pseudechis* in 0·1 per cent. solution destroyed the red corpuscle.

Flexner and Noguchi showed that these hæmolysins must be looked upon as amboceptors, which require a complement, and this they obtain in the bactericidal principles found in the serum of the victim. Hence, when they join with the erythrocytes and the complement, they not merely produce hæmolysis, but they take away the bactericidal powers from the blood. If, as was found to be the case in *Necturus*, they are incapable of uniting with the complements, they are incapable of damaging the bactericida properties of the serum; for it was found that hæmolysis was bu slightly produced in the blood of *Necturus*, and then only afte long periods, and at the same time the serum of *Necturus* did not lose its bactericidal effects to *Bacillus coli communis* and *B. typhosus*.

The hæmolysins have been further studied by Kyes, who showed that in some animals the venom alone could hæmolyze the washed red cells, whereas in others it could not do so until some fresh serum was added. In the first class came man, dog, rabbit, guinea-pig and horse, and with reference to these he came to the conclusion that the complement was contained in the red blood cell itself —*i.e.*, was an endocomplement. In a further research with Sachs, he shows that this endocomplement is attached to the stroma of the red cells. Further, they conclude that it is the lecithin of the stroma which acts as the complement, and support this by experiments showing that lecithin prepared from the yolk of an egg can act as a complement for the venom, and dissolve cells which are not affected by the venom alone. They look upon the fatty acid radical of the lecithin as being probably the active agent.

In the second class—viz., those animals whose erythrocytes are not affected by venom alone without the presence of serum—come the ox, sheep, and the goat; but Kyes found it very easy to produce solution by the addition of foreign sera—*e.g.*, ox blood by venom and guinea-pig serum; sheep blood by venom and guinea-pig serum—which clearly showed that the venom was an amboceptor, and agreed with the results of Flexner and Noguchi.

Further, he showed that by heating the serum to 56° C. for half an hour this action was destroyed, but if heated to 65° C. for half an hour hæmolysis took place. In other words, serum contained two possible complements: (1) free in the serum, and destroyed by heat; (2) only in heated serum. Kyes and Sachs consider (1) to be complements in the restricted sense of the term, and that there are differences in their workings from that of the lecithin complement. More recently, however, they have doubted this, and begun to believe that the serum merely frees the lecithin, which acts as the true complement.

In (2) the lecithin, being free, is able to combine with the amboceptor and cause the hæmolysis. They further show, that if a blood solution is heated to 62° C., it is inactivated, owing to the union at this temperature, of the lecithin directly to the hæmoglobin.

They therefore came to the conclusion that the reason why there was a difference in the action of the venom on red cells was that in the first class—*e.g.*, man, etc.—the lecithin was so loosely bound to the cell that it was available as a complement for the venom amboceptor, whereas in the other cases it was more closely bound, and therefore was not available.

Kyes then went a step further, and mixed 40 c.c. of a 1 per cent. solution of cobra-venom in a 0·75 per cent. salt solution, with

20 c.c. of 20 per cent. solution of lecithin in chloroform, and then centrifugalized the mixture. The result was the separation of chloroform and water into two layers; from the former the cobra-venom lecithin can be precipitated by the addition of pure ether. This body possessed hæmolytic but no neurotoxic properties, which entirely remained in the water. Thus Kyes clearly supports the fact first pointed out by the late Dr. Myers that the neurotoxic and hæmolytic actions are quite separate.

This cobra-venom lecithin differs in many of its properties from cobra-venom and from lecithin—*e.g.*, it is soluble in water, which lecithin is not; it is soluble in alcohol, chloroform, and toluol, which the cobra-venom amboceptor is not.

Kyes found that the lecithin was active with the blood cells of all the species he examined, and that the absolute quantity necessary for hæmolysis was the same for the blood cells of different species. Thus lecithin corresponding to 0·003 milligramme of the dry cobra-venom was capable of hæmolyzing 1 c.c. of a 5 per cent. suspension of the erythrocytes of guinea-pig, rabbit, man, or ox.

The lecithide acts very quickly on the red cells (twenty-four times more quickly than the venom), which is due to the fact that no time is spent in developing the real toxic agent—*i.e.*, the lecithide.

The lecithide is not destroyed by heating to 100° C. for six hours, and is little affected by Calmette's serum.

Kyes went further, and studied the lecithides of—(1) *Lachesis anamallensis* Günther; (2) *L. lanceolatus* Lacép; (3) *L. flavoviridis* Hallow; (4) *Crotalus durissus* L.; (5) *Vipera russellii* Shaw; (6) *Naja bungarus* Schleg; (7) *Bungarus candidus* L.; (8) *B. fasciatus* Schn.

All these poisons, on the addition of sufficient lecithin, destroy blood cells, and, except in the first and the third, the absolute quantity of the poison is the same as that mentioned just above.

That of *Lachesis anamallensis* Günther is, however, twenty-five times weaker, and *L. lanceolatus* Lacép ten times weaker, this being due to the fact that the former forms only one-twenty-fifth and the latter one-tenth the usual quantity of lecithide.

Hence Kyes concludes that the hæmolytic element in all snakes is an amboceptor possessed of a haptophore group for the erythrocyte, and a toxophore group for lecithin, which contains the active element for the hæmolysis. The haptophore group, however, probably differs in different poisons, for Lamb has shown that, while cobra-venom will unite with Calmette's antitoxin, poison of *Vipera russellii* will not. *Bungarus* and *Naja bungarus* act like the cobra, and *Lachesis* and *Crotalus* do not.

Noguchi investigated lecithin, and found it to be by no means an inert substance, and, further, that certain oleic compounds and oleic acid itself would act as venom activators.

He found that the addition of oleic acid or its soluble soaps to a non-activating serum in the ratio which corresponds to the percentages of fatty acids and soaps contained in some of the easily activating sera makes it highly active to venom. In the normal serum of a dog, however, he found that there was a lecithin compound acting like free lecithin. He further found that these two classes of activators could be differentiated from one another by calcium chloride, which annulled the first group, but was powerless against the lecithide. Non-activating sera do not contain this lecithin compound, and other lecithides—*e.g.*, lecith albumin—are powerless.

When serum is heated, the non-coagulated portions contain a lecithin activator, as described by Kyes, which is identical with Chabrié's albumon ; but this does not exist preformed in unheated sera, and is due to the high temperature altering other proteid lecithides into albumon.

He further found ovovitellin to be one of the best lecithin proteid activators. He finally came to the conclusion that the reason why some red corpuscles (man, etc.) are acted upon by venom, while others (ox, etc.) are not, depends solely upon the amount of fatty acids, and perhaps also of soaps and fats, contained in the corpuscles, to the stroma of which they are attached. They exist plentifully in corpuscles easily affected, and in small amount in those not easily affected.

The position at the present moment is, therefore, that snake-venom produces hæmolysis by its amboceptors uniting with complements contained in the sera of the majority of mammals and birds investigated, and that these complements are fatty acids and soaps (belonging principally to the oleic series).

Further, there are endocomplements in the erythrocytes of certain species, and these are of the same nature as those in normal sera, and are attached to the stroma of the corpuscle.

Finally, the reason why heated sera become active at high temperatures after losing their activity at lower temperatures is because of the conversion of the proteid lecithides into another form of lecithide called albumon, which is an activator.

(*b*) *The Leucolysins.*—Weir Mitchell and Reichert had noticed in their researches that the mobility of leucocytes absolutely ceased in crotalus poisoning. Martin studied this carefully with Pseudechis-venom, and says that for the first fifteen minutes he could see no change in the white cells, but they exhibited no amœboid movements. At the end of this time the nuclei in some of them were very distinct, as if fixed by acetic acid. They then became intensely granular, and soon began to swell, and their outlines to grow less distinct, until they disappeared, leaving only a small heap of granules.

Flexner and Noguchi studied this phenomenon, and found that leucocytes with large coarse granules were most quickly affected next came the fine granular varieties ; and last of all the lymphocytes. They found cobra poison much more vigorous than that of crotalus. As to the leucolysins, they proved that they were separate from the hæmolysins by treating washed red corpuscles with copperhead venom until the supernatant fluid, after centri fugalization, ceased to have any effect on red cells. This fluid was then brought into contact with leucocytes, when lysis without agglutination took place. If, however, washed leucocytes were treated first, the supernatant fluid was found to be actively hæmolytic. They therefore concluded that the hæmolysins were distinct from the leucolysins, but that the agglutinins were probably the same.

We are not aware of further researches as to the nature of the leucolysins, though obviously such researches are required.

(*c*) *Hæmorrhagin.*—Weir Mitchell and Reichert, by observing a mesentery moistened with crotalus-venom, came to the conclusion that the blood escaped from the vessel owing to damage to the wall.

Flexner and Noguchi found that by heating crotalus-venom to 75° C. for thirty minutes, this hæmorrhagic power was lost, and along with it most of the toxicity, as ten or twenty M.L.D. were required to cause death with symptoms resembling cobra-venom. They conclude that this death must be due to the neurotoxic or hæmatoxic properties (hæmolysins and agglutinins) in the venom, and that, as the latter can be eliminated without any apparent loss of toxicity, it must be due to the neurotoxins.

The toxic principle lost by heating to 75° C. Flexner and Noguchi called hæmorrhagin. They studied its action in the mesentery by injecting the venom into the peritoneal cavity, or placing a minute particle of the dried poison on the exposed mesentery, and then removing specimens, which they fixed in Zenker's fluid, cut into sections, and stained with hæmatoxylin and eosin. They found that the extravasation of blood took place not by diapedesis, but through actual rents in the walls. These rents are not simple ruptures, but are apparently due to a cytolytic action upon the endothelial cells of the capillaries and the walls of the small veins.

(*d*) *Other Cytolysins.*—Flexner and Noguchi have found that the amboceptors in venom can act upon a number of the cells of the body—*e.g.*, liver, kidney, testicle, and ovary—causing lysis, the complement being probably either endocellular or in the lymph-stream. The nature of the complement is, however, quite unknown at present, but is probably different from the complement acting on the red cells, as its activity is destroyed by heating to 60° C. for some time. The histological effects of these toxins can be noted particularly in the microscopical appearances in the liver and kidney. The liver shows necrosis and fatty degeneration of its cells, and, as a reactionary process, leucocytic infiltration around the bile-passages. In the kidney, the glomeruli show intense congestion of their capillaries, often associated with ruptures of their walls and hæmorrhage into Bowman's capsule. The cells of the tubules are necrotic and detached, filling the lumen. The whole organ is congested, and there may be interstitial hæmorrhages. The spleen is but slightly affected.

4. ANTIHÆMOLYSINS.—Weir Mitchell and Stewart have shown

that if crotalus-venom is added to red corpuscles in a certain degree of concentration, no hæmolysis takes place. This fact has been confirmed by Myers and Stephens for the cobra, and Lamb for *Vipera russellii.*

Noguchi believes that the action is due to venom having the power in certain cases of precipitating the outer layer of the hæmoglobin, while in other cases this does not take place.

5. Antibactericidal Substances.—Weir Mitchell drew attention to the fact that bodies of animals dead from crotalus poisoning rapidly decomposed, while Ewing found the normal germicidal power of the serum was destroyed—a fact confirmed by Martin.

Flexner and Noguchi also investigated this action, and came to the conclusion that—

(1) All venoms, when used in suitable quantities, destroy the bactericidal properties of many normal sera.

(2) The manner of this destruction consists in the fixation of the serum complements by the venoms.

(3) Venoms have no action upon the intermediary bodies of the serum.

6. Fibrin Ferment.—A fibrin ferment has been shown by Martin to be present in the venoms of the viperidæ and also of some of the colubridæ. In the former it is the active agent which causes the vascular clotting in small animals with convulsions and sudden death.

7. Anti-fibrin Ferment.—An anti-fibrin ferment—that is to say, a substance which in minute quantities is able to prevent the coagulation of the blood—is found in cobra and allied venoms.

8. Proteolytic Ferment.—Venom contains a body of some description, probably a ferment, which is capable of transforming proteid.

Thus, Mitchell and Reichert long ago showed that muscle-fibres at the site of the bite were quickly softened by crotalus-venom, and Flexner and Noguchi have shown that gelatine is liquefied by both crotalus- and cobra-venoms, but that coagulated proteids are not acted upon. Microscopically the muscular fibres at the site of the bite are seen to have undergone necrosis and degeneration, and later a polymorphonuclear leucocytic infiltration may be noted.

9. Cardiac and Vascular Tonic.—Sir Lauder Brunton and Sir Joseph Fayrer showed that the poisons of the cobra had a stimulant effect on the heart, and that the circulation could be kept going for a long time after complete failure of breathing if artificial respiration is kept up—a fact of considerable importance if any antidotal treatment is available.

It is not clear whether this is due to direct action on the muscles of the heart, but it appears from Rogers' experiments that the effect on the bloodvessels is due to local action on the arterioles. This effect is produced by the cobra and *Vipera russellii* venom.

Entry of the Venom into the Body.

The poison, the characters of which have been described, is introduced into the body of man or that of an animal usually by the snake biting the skin and injecting the poison either subcutaneously or into a vessel. In the former case it will soon reach the bloodstream, and be distributed to the different parts of the body.

The effect of entry into a bloodvessel is to produce immediately the signs of the poisoning, whereas in the subcutaneous tissue it may take some time, and even be modified, especially in the viperine type.

If the venom fall on the conjunctiva it is readily absorbed, and symptoms of poisoning will ensue, or an acute inflammation be set up.

Taken by the mouth, the venom of the colubridæ is harmless, provided there are no cracks or abrasions, and is destroyed by the saliva and pancreatic juice. Viperine venom, on the other hand, causes gastritis, gastro-intestinal hæmorrhage, and even death, without the appearance of the usual symptoms, a fact known to the natives of Ceylon with regard to the venom of *Vipera russellii.*

Minimum Lethal Dose (M.L.D.).

The minimum lethal dose varies with the species of snake, the condition of the snake, and with the species of the victim.

Tables are given by Calmette, and Martin and Lamb, showing the amount for different snakes and animals. Thus, the quantity of cobra-venom required to kill a kilogramme of a dog is 0·0008 gramme, and of a rabbit 0·0005; and that of *Bungarus candidus* for a rabbit is 0·0008 gramme, and that of *Enhydrina valakadien* for a rabbit is 0·00006 gramme, while the same for a cat is 0·0002. Putting it in another way, 1 gramme of cobra-venom will kill 1,250 kilogrammes of dog, 2,000 of rabbit, 2,500 of guinea-pig, 1,500 of rat, and 8,333 of mouse, and 20,000 grammes of horse.

Calmette calculates that, taking a man of average size, the minimum lethal dose might be halfway between the dog and the horse—*i.e.*, would be 0·015 gramme of cobra-venom—and 1 gramme will kill 10,000 kilogrammes of man, or 165 persons of the weight of 60 kilogrammes; but, of course, this is only a very approximate guess. Lamb calculates the M.L.D. for man to be 0·015 gramme of cobra-venom, and Fraser puts the same at 0·031 gramme.

Lamb gives a number of minimum lethal doses for snakes calculated per kilogramme of rabbit and injected intravenously, which are:—

Bungarus candidus	0·00004	gramme.
Enhydrina valakadien	0·00005	,,
Vipera russellii	0·0001	,,
Naja tripudians and N. bungarus..	0·00035	,,
Bungarus fasciatus	0·0007	,,

Effects of the Venom.

The effects of the venom have been carefully studied on warm and cold blooded animals by many observers for a long series of years, but there is a distinct difference in the action of different kinds of venom, and therefore it is as well to discuss the effect of each separately.

But in doing this it will be noted that it is difficult to obtain undoubted cases of bites by definitely known snakes in man, and even when these are obtained the urgent necessity for treatment causes the symptoms to be little noted. Therefore it is necessary to detail first the experiments on animals, and then the symptoms found in man.

Colubrine Venom—*Naja tripudians Merr.*—The experiments of numerous observers show that the effects of this venom on animals are:

1. Paralysis of voluntary movement.
2. Salivation.
3. Marked effect on the respiration, which ceases before the heart.

In smaller quantities the paralysis becomes more marked, and in cases of longer duration several features are added.

1. Local inflammation where the bite was inflicted.
2. Lachrymation.
3. Mucous discharges from the nose, respiratory organs, and stomach.
4. Very occasionally the mucous discharges are stained with blood.

Beyond obvious pain, the local effects are engorgement of the vessels with blood, and effusion into the tissues. If the animal recovers, there may be suppuration and sloughing of the affected part. The effects on the nervous system seem to be due to the action of the poison on the brain and spinal cord, and *pari passu* on the motor nerve endings. The most evident paralysis is that of the tongue, larynx, and pharynx, as evinced by the inability to retain the saliva within the mouth, to move the tongue, or to swallow. This is due to the action of the poison on the medulla.

There is also, as indicated above, clear evidence of action upon the respiratory centre, which has been carefully studied by Wall and others, who show that in large doses there is a progressive slowing, and in smaller doses first acceleration and then slowing of the respirations. There appears to be but little effect upon the heart and circulation or temperature.

The effect on the blood in causing hæmolysis was first demonstrated by Cunningham, who considered it the main feature. Not merely are the corpuscles dissolved, but the coagulability is reduced, and hence the blood-staining of the tissues and the urine in experiments on animals, provided that artificial respiration is kept up.

The effects of the venom on man are local pain in the neighbourood of the bite, which appears as two small punctures about ¾ inch part, usually exuding a blood-stained fluid. The pain increases in everity, and spreads up the limb on to the body. In a short time he victim feels intoxicated, and presently loses control of his legs. hich become paralyzed, as may other muscles, including those of he jaw. There is often profuse salivation, and inability to speak r swallow. The pulse and respirations increase for a time, and hen the breathing becomes slower, and death occurs from failure f the respiration, while the heart continues to beat for a short ime after the respirations have ceased.

If recovery takes place, the urgent symptoms abate, some slight ever and local swelling occurs, while a large amount of urine is assed.

When examined post mortem, it will be found that the rigor nortis is well marked, while the blood is fluid in man, but coagulated n animals. If the corpuscles are examined soon after death, no hange will be noted, but later they alter, and blood-crystals, ndicating hæmolysis, may form. The parotids may be swollen. The brain is normal, but the pia mater is gorged with blood. The muscles are often of a dirty red colour. The lungs in human beings are generally congested, and the bronchi and smaller tubes filled with thin frothy fluid and intensely congested. Particles of food or remedies are to be found in the air-tubes because of the paralysis of the larynx. The right heart is distended with blood. The liver is congested and dark. The kidneys may be normal or intensely congested. The intestines show nothing in particular. The bladder is contracted.

Microscopically, fatty degeneration of the liver and kidney, and necrosis of hepatic and renal epithelium, are to be seen, as well as round-celled infiltration along bile-ducts, which is probably due to excretion of poison.

Turning now to the colubrine snakes, which resemble the cobra, there are observations upon *Naja haje*, *N. bungarus*, *Bungarus candidus*, *B. fasciatus*, and the *Hydrophidæ*.

Naja haje L.—Calmette records that Dr. Deschamps observed a case of this bite in Senegal in which the snake bit the patient on the forehead. Almost immediately great weakness, accompanied by nausea and pains in the head and neck, set in. Locally two raised areas were seen, around which the tissue was œdematous. Cold sweats occurred. The œdema spread to the face, dyspnœa appeared, and the pulse became small and intermittent, paralysis set in, and the patient became comatose, but recovered on treatment with antivenene.

Naja bungarus Schleg.—*N. bungarus*, the hamadryad, is by far the biggest of the Indian poisonous snakes. Rogers finds its venom very like that of the cobra, producing paralysis and death from failure of respiration, while the heart continues to beat for a time.

There is no intravascular clotting, and the hæmolytic action is very slight, but the phrenic nerve-plates are paralyzed. If small doses are given, the respirations are increased.

We are not acquainted with the symptoms exhibited by an undoubted case of this bite in a human being.

Bungarus candidus L.—As to *B. candidus* L., the commonest of all Indian snakes, there is not much to say, except that all researches (Fayrer, Wall, and Rogers) indicate that it is almost exactly the same as that of the cobra, but is slightly more virulent.

Cases of this bite are common. In brief, the symptoms are: a sense of tightness across the chest, with paralysis, particularly of the muscles of the face, deglutition and phonation. The conjunctivæ are suffused, the pupils dilated, the pulse and respirations quickened; the temperature is normal, and the local signs are not marked.

Coma and convulsions precede death, which is due to failure of respiration. Congestion of the meninges and brain and liquid blood are the principal signs found post mortem.

Bungarus ceylonicus (Gthr.).—*B. ceylonicus*, the Ceylon krait or carawala, has been reported by Green to have killed a man in twelve hours. The man was bitten on the left foot at 4 a.m., and felt quite well till 5.30 a.m., when he felt drowsiness, which increased till 10 a.m., when he could hardly swallow and was very sick. Paralysis affected his legs, and he became cold. Artificial respiration was now resorted to, but at 2 p.m. he became very feverish and insensible, and died at 4 p.m.

Bungarus fasciatus Schn.—The effects of the poison of *B. fasciatus* have been carefully studied by Wall, Lamb, and Rogers.

In acute cases death takes place quickly from failure of respiration; the blood is coagulated, and there is paralysis, and sometimes convulsions.

Chronic cases, on the other hand, last for days, during which there is loss of weight and emaciation, and perhaps some paralysis.

Microscopical examination of the cortex of the brain, medulla, and spinal cord shows diffuse chromatolysis, affecting a very considerable portion of the ganglion cells, being most marked in the cortex, next in the cord, least in the medulla. The cells show a rather deeply stained plasma, in which are scattered dust-like granules, the remnants of the Nissl bodies; many cells show vacuolation of the plasma, and some are reduced to mere outlines (ghost cells).

Rogers' experiments tend to show that even in injecting large doses the blood may not clot, and that the animal may be killed, as in cobra-venom, by direct action of the poison on the respiratory centre, and also on the nerve-endings of the phrenics, so that the venom appears to be a mixture of a viperine with a colubrine poison.

The only authentic case of human poisoning by *B. fasciatus* is mentioned by Fayrer, in which there was tingling sensation and later pain at the seat of the punctures, with some swelling, all of which disappeared in less than twenty-four hours.

The Hydrophidæ.—Rogers experimented with *Enhydrina vala-*

kadien Boie, *Distra cyanocincta* Daud, and *Hydrophis cantoris* Gthr., and came to the conclusion that their venom only differed from that of the cobra in the following points :—

1. They were more toxic.
2. They were much less hæmolytic, and hence caused no blood-stained effusion at the site of the injection.
3. They did not affect the coagulability of the blood ; therefore the poison is almost purely neurotoxic.

There is at first an excitation of the nervous system, leading to a feeling of activity and vivacity, which, however, soon passes off. The earliest signs of distress begin with difficulty of articulation and feeling of stiffness in the body and of suffocation. The stiffness in the muscles increases, and occasional spasms occur, while signs of gastric irritation, with vomiting, appear. Convulsions and death may ensue after a day or so. The local signs may be slight.

Viperine Venom.—*Vipera russellii* Shaw, the *tic polonga* of Ceylon, is a good example of this type of venom. Wall's experiments show that a dog bitten by one of these vipers will become convulsed, and die within five minutes. The cause of this sudden death has been shown by Rogers to be intravascular clotting, which is best marked in the portal vein, and then only in small animals. Post mortem, there are hæmorrhages into the area of the bite, and into kidney and intestine.

In addition to these acute cases, there are also chronic cases, in which the local symptoms are more or less extensive subcutaneous hæmorrhages, around which there is much œdema. This hæmorrhage may be absorbed, or the area may slough, or an abscess, or even a spreading gangrene, may ensue.

The general symptoms are rapid emaciation, profound anæmia and lethargy, and in some cases hæmaturia and a discharge of blood from the bowel.

Rogers has carefully investigated these symptoms, and has pointed out that there is a remarkable fall of blood-pressure due to vasodilatation of the portal system, caused by action of the poison on the central, and not the peripheral vasomotor apparatus, the heart muscle being unaffected. Lamb and Hanna showed that in chronic cases there is deficiency in the blood coagulability.

In man there are the two small punctured wounds caused by the fangs, around which the skin is swollen and livid and painful. The swelling and discoloration spreads, and in the course of twenty-four hours the patient becomes at first excited, with thready pulse and hurried respirations, and later stuporous. The skin is clammy and covered with a cold sweat, while the swelling and discoloration spreads considerably, reaching the trunk. In due course convulsions set in, and death ensues from failure of the circulation. The post-mortem reveals congestion of the meninges and lungs with fluid blood, and nothing else of importance.

Bitis arietans.—The puff-adder poison was found by Rogers to work in much the same manner as that of *Vipera russellii*, but not so poisonous.

Echis carinata.—This is a very poisonous snake, and the effects its bite resemble that of the cobra.

Wall records a case in which there was much local swellin passage of blood in the urine, fæces, and vomit, elevation of temper ture, and death from exhaustion, due to loss of blood, on the nin day. Martin and Lamb record another case in which there was mu swelling of the bitten part, due to exudation of liquid blood. Pa and tenderness were felt along the nerves, together with anæsthesi extreme restlessness, with cold and clammy extremities, but hæmorrhages. Loss of consciousness, with delirium, set in only short time before death, which took place at the twenty-fifth hou

Fayrer gives a good account of a chronic case, in which there w depression and faintness, coldness of the extremities, with swelli of the affected part, and marked hæmorrhages from eyes, gum throat, nose, vagina, and under the nails.

The Crotalidæ are typically represented by *Crotalus horridus* America, which has been carefully studied by Weir Mitchell a Reichert, and by *Lachesis*, which has been studied by Rogers India.

Crotalus horridus.—The local effects are: œdema, swelling, darke ing of the parts with infiltration of incoagulable blood, breaki down of the tissues, putrefaction, and sloughing. There is no clo ting of the blood, which, on the other hand, is fluid and incoagulab There is a marked fall of blood-pressure, and respiration gradual ceases, due to the failure of the circulation, but there is no dire effect on the respiratory centre, and the phrenics are not paralyze The heart goes on beating after respiration ceases, but is slight weakened. Post-mortem examination shows hæmorrhages into t peri- and endo-cardium, and into the peritoneum and pleura, b not in the brain or the medulla, while the whole portal system much congested.

Rogers placed a loop of small intestine in an oncometer, and fou that fall of blood-pressure was associated with a vaso-dilatation the portal system, in which the blood is not clotted. This vas dilatation he considers may possibly be due to the action of t venom on the vasomotor centre in the medulla, and thinks th he is supported in this theory by the appearance of Traube-Herri curves in his blood-pressure tracings.

Weir Mitchell and others have carefully collected the sympto following this bite. In most instances the bite is painful, a the part becomes swollen and discoloured, while both the pa and the swelling increase steadily. The swelling is due to t effusion of blood. Very seldom is there any lymphangitis enlargement of the lymphatic glands. Vesication, sloughing, a gangrene may result if life is prolonged and the dose considerab If, on the other hand, the amount of poison injected is inconsid able, the swelling declines, and the pain disappears very quick

Constitutional symptoms are said by some people to begin directly after the bite, but this is hardly likely, as man is a relatively large animal. Under exceptional circumstances it is recorded that the symptoms did not begin till about thirty minutes after the bite, but usually the length of time is only a few minutes. The person feels extremely faint, or complains that his lower limbs are not able to support him. There is no primary stimulating effect like that mentioned in other venoms. The patient staggers or falls, cold sweats bathe the surface of the skin, and nausea and vomiting occur. The pulse is rapid and feeble, the expression anxious, and, according to Mitchell, in a few cases the mind may be slightly disturbed, but this may be largely due to fear. If the patient does not die at this stage, the local symptoms mentioned above become very pronounced, and signs of general blood-poisoning show themselves, and often lead to death.

The post-mortem reveals that the brain is normal, but congested and somewhat œdematous ; the trachea and bronchi are congested, and full of red frothy mucus ; while the lungs are healthy, but somewhat congested. The peritoneum may contain a little fluid, and the mucosa of the stomach and small intestines may be intensely congested and infiltrated with serum. In some cases the blood is coagulated, in some it is fluid. The local swelling is due to serous exudation. The chief features of the post-mortem are vaso-dilatation of the portal system and fluidity of the blood.

Lachesis.—This snake shows the same symptoms as *Crotalus*, but it has some effect upon the respiratory centre, causing quickening of respiration before the slowing begins. The phrenics are not paralyzed.

Moreover, it is possible that the first quick fall of blood-pressure observed is due to action of the poison on the heart, but the subsequent steady fall is due to the action on vasomotor centres, as in *Crotalus*.

Kitajima says that the region of the bite becomes dark purple in colour and swells ; that the pain is severe and burning ; and that the lymph glands become enlarged and tender. The face is pale, the pulse feeble and rapid. Respiration is normal ; a slight fever is not infrequent. Coldness of the extremities, with dyspnœa and cold sweats, come on just before death. Blood has been observed in the urine and fæces.

Excretion of the Poison.

It is believed that the poison leaves the body principally by the kidney, and to a less extent by the mucosa of the stomach, the salivary and mammary glands.

With regard to the kidney, there is some direct proof of the excretion, because the urine of a dog poisoned by *Enhydrina valakadien*, when injected hypodermically into a pigeon, caused death in twenty-two hours.

It is also stated that 1 drachm of the saliva of a dog poisoned b
a cobra was capable of causing death in two hours.

With regard to excretion by the mammary glands, an infant i
said to have died after suckling the breast of a woman bitten by
poisonous snake.

Immunity.

Having considered the chemical composition and physiologica
action of the venom, the next point to be discussed is immunity t
its action.

Ancient and modern people have equally held the belief that a person wh
has been bitten by a poisonous snake and survived obtains some sort o
immunity; generally the belief has been that this immunity is capable o
protecting the individual against all kinds of snakes.

Ancient fables credited the Psylli of Africa, the Marsi of Italy, and Gouni of India, with immunity on the ground that they had snake's blood in their veins.

The pig was long thought to be naturally immune; but this is a mistake, for the relatively slight effect of snake-venom is due to the presence of the thick layer of but slightly vascular fat which surrounds the animal's body. The mongoose (*Herpestes ichneumon*) is believed to be naturally immune to cobra-bite.

Acquired immunity is said to occur among natives, especially snake-charmers, and Europeans who have been bitten several times by snakes. The Eisowy of Western Barbary are said to have acquired such an immunity, and to allow themselves to be bitten by snakes proved afterwards to be poisonous by killing a fowl. The natives of Bushmanland, Namaqualand, and Damaraland are said to drink the venom of snakes as a protection. In Ceylon a cobra is said to have bitten a snake-charmer, and shortly afterwards a bystander. The snake-charmer escaped without symptoms; the bystander died.

The first scientific attempt to produce an artificial immunity was made by Sewall in 1887, when by repeated small injections he raised the resistance of pigeons so high that they were able to resist ten times the minimum lethal dose of the venom of a *Crotalus*. Kanthack also produced a partial immunity to cobra-venom in 1891. Kaufmann, a little later, obtained a similar result with the French viper.

In 1892 Calmette showed that by repeated inoculation of venom heated to 80° C. a certain amount of resistance was produced in animals. In 1894 he made researches on the venom of the cobra, and about the same time Phisalix and Bertrand investigated that of the viper, and showed that animals vaccinated with venom developed a true immunity, and those inoculated against the cobra-venom were able to resist mortal doses of *Vipera*, *Bungarus*, *Cerastes*, *Naja haje*, and *Pseudechis* venoms. Later they showed that the serum of an animal vaccinated by snake-venom contained antitoxins capable of producing an immunity in new animals.

Calmette obtained his serum from horses, but with great difficulty, as many of the animals died in the course of treatment from endocarditis and acute nephritis, while in others abscesses formed.

He found that in a fresh horse 0·025 gramme of cobra-venom was sufficient to kill the animal in twelve to twenty-four hours, but on vaccinating the animals for sixteen months, it was found that a horse could stand without reaction the injection of 2 grammes of cobra-venom—*i.e.*, eighty times the M.L.D.

From such a horse it was found possible to withdraw as much as 20 litres of blood in three bleedings spread over ten days, the serum being considered to be ready for use when 1 c.c. mixed with 0·001 gramme of cobra-venom produced no sign of intoxication when injected subcutaneously into a rabbit, and when, after injecting 2 c.c. of the serum into a rabbit of 2 kilogrammes weight, two hours later 1 milligramme of venom could be injected without results. This serum was said to preserve intact its antitoxic value in all climates. The venom used for these injections was principally that of the cobra, with a slight admixture of other venoms.

In 1895-96 Fraser of Edinburgh confirmed Calmette's results, and believed that if an animal was so successfully vaccinated that it could resist the minimum lethal dose of one venom, it would also be able to resist that of other venoms. He believed that venom introduced into the stomach conferred immunity.

In 1897 C. J. Martin showed that Calmette's serum did not preserve animals against the venom of *Notechis scutatus.*

From 1901 onwards Lamb in India studied carefully the effects of snake-venoms, and came to the conclusion that Calmette's serum is active against cobra-venom, but is not useful against that of *Vipera russellii*, *Bungarus fasciatus*, or of *Echis carinatus.*

In 1902 Tidswell showed that serum prepared from the venom of *Notechis scutatus* did not neutralize the venoms of the cobra, *Bungarus fasciatus*, or *Vipera russellii*, and, further, had no effect on the venoms of the brown and black snakes and death-adder of Australia.

In the same year Lamb pointed out that there was a precipitin in venom-immune sera, and this point being further investigated by Hunter, the deduction was made that these precipitins were specific, and due to the coagulable proteids.

The following pure sera have been prepared :

1. *Lamb's Pure Naja Tripudians Meer Serum.*—This serum is strongly antitoxic for cobra-venom, and in large doses for *Enhydrina valakadien* Boie, but has no effect upon *Bungarus candidus* L., *Brachyaspis curta* Schleg, *Echis carinatus* Schn., *Lachesis gramineus* Shaw, *Vipera russellii* Shaw.

It delays death in *Bungarus fasciatus* Schn., *Naja bungarus* Schleg, *Crotalus durissus* L.

2. *Lamb's Pure Vipera Russellii Shaw Serum.*—This serum neutralizes the venom of *Vipera russellii* and *Crotalus durissus*, but has no action upon—Colubridæ : *Naja tripudians* Meer, *N. bungarus* Schleg, *Bungarus candidus* L., *B. fasciatus* Schn., *Enhydrina valakadien* Boie ; Viperidæ : *Echis carinatus* Schn., *Lachesis gramineus* Shaw.

3. *Tidswell's Pure Notechis Scutatus Ptrs. Serum.*—This serum has a strong antitoxic effect upon the venom of *Notechis scutatus*, but has no effect upon that of—Colubridæ : *Naja tripudians* Meer,

N. bungarus Schleg, *Bungarus candidus* L., *B. fasciatus* Schn *Enhydrina valakadien Boie*.. Viperidæ: *Vipera russellii* Sha *Echis carinatus* Schn., *Lachesis gramineus* Shaw, *Crotalus durissus*

4. *Noguchi's Pure Crotalus Serum.*—It has a strong effect upo *Crotalus* venom, and a slight effect upon *Ancistrodon piscivor* Lacép, and none on the cobra.

5. *Noguchi's Pure Ancistrodon Piscivorus Lacép Serum.* — Th has a marked effect upon moccasin-venom, and medium effect upo *Crotalus*, and none on cobra-venom.

6. *Brazil's Pure Crotalus Horridus L. Serum.*—This serum is equall efficient for the venoms of *Crotalus horridus* or *C. durissus*, but useless for cobra-venom.

The Caracas Commission reports that this serum is more efficacio against the venom of *Crotalus* than that of Calmette, which fa to neutralize the hæmorrhagins.

7. *Kitajima's Pure Lachesis Flavoviridis Hallow Serum.* — Th serum is specific for *Lachesis* venom, against which Calmette serum is useless.

It is clear that the antisera mentioned above are very nearl specific, for they neutralize principally the venom of the speci employed, and sometimes in larger doses that of some allied specie It is obvious that this is of great importance in considering th serum treatment of snake-bite.

8. *Polyvalent Sera.*—Polyvalent sera prepared for more than tw venoms are not very efficacious.

Diagnosis.

It might be thought that the diagnosis of snake-bite would b obvious, and that nothing need be written on the subject, but th is not always so, because snake-bite often takes place in the dar and the nature of the snake is unknown.

The diagnosis may be divided into two heads: (1) Has a snak bitten the person? (2) Was the snake a poisonous one?

The first thing to do is to tie a proximal ligature on the limb, an then to examine the area of the supposed bite. If there ar absolutely no fang-marks and no venom on the skin, then obviousl there is no danger; but fang-marks on the skin or venom o mucous membranes (which, of course, may have cracks) or on ski with scratches may be dangerous.

If there are no fang-marks, and the snake is forthcoming, examin it to see whether it is poisonous or not, especially to see wheth there are fangs, and if non-poisonous, the patient's mind can b relieved at once.

Prognosis.

It appears that only a relatively small percentage of perso bitten by snakes (supposed to be poisonous) die. C. J. Martin an Lamb place it about 30 per cent., but much depends upon th quantity of venom injected and the rapidity with which symptoms develop. Personally, we believe that in most cases if treatment has been prompt, and the symptoms appear slowly, the outlook is by no means hopeless.

Treatment.

Snake-poisoning consists in the hypodermic or intravascular injection of a series of poisonous principles which act chiefly upon the nervous system and the blood.

The virulence of the poisoning depends upon the ratio of the quantity of the poison injected to the size of the animal. The same quantity of poison will therefore have a more serious effect upon a child than upon an adult. The less the quantity of poison which gets into the general circulation, the less the symptoms; hence the first indication for treatment is to prevent the passage of the poison, as far as possible, into the circulation.

The second indication for treatment is to neutralize the poison which has got into the system, and the third indication is to treat special symptoms as they appear.

1. **Prevent the Poison getting into the General Circulation.**—In order to prevent the poison getting into the general circulation, three points must be attended to:

(1) Stoppage of the flow of blood and lymph from the affected area.
(2) Free opening of the poisoned area.
(3) The neutralization of the poison locally.

(1) *Stoppage of the Flow of Blood and Lymph from the Affected Area.*—A person is usually bitten in the arm or leg, and in such a case the old treatment advised by Celsus should be carried out by applying a tight ligature round the affected limb on the proximal side of the wound, so as to compress the blood and lymphatic vessels. In order to do this successfully, the ligature must be applied to the arm or the thigh—*i.e.*, where there is one bone—and not the forearm or leg.

Such a ligature cannot be left in position indefinitely, otherwise gangrene will result; and after some attempts at neutralization of the poison have been made, it must be loosened for a couple of seconds and reapplied, and this must be repeated. It must be kept on for at least twenty or thirty minutes.

The advantages of the ligature or tourniquet have been known since ancient times, but recently C. J. Martin has shown that its principal action with colubrine poison is not merely to delay the absorption of the poison, but also to give time for any already absorbed to be excreted. In the viperine poisons which coagulate the blood by fibrin ferment it is most beneficial; for the blood, in coagulating locally, retains the poison, which therefore but slowly passes into the general circulation, and may, as Martin and Lamb suggest, unite with the cells near the bite.

There is therefore no doubt that the correct immediate treatment in a bite due to any kind of poisonous snake on a limb is the appli tion of a proximal tourniquet.

(2) *Free Opening into the Poisoned Area.*—It will be obvious t the two minute punctures caused by the fangs are not sufficien large openings into the area of the bite for the application of antidot

Therefore the next step is to cut, not merely round the apertu of the fangs, but also to extend the incision along the course of t veins and lymphatics, and in some cases to remove the piece of sk marked out. In this way the area of inoculation is freely opene

(3) *Neutralization of the Poison Locally.*—The next indication is diminish the toxicity of the poison as much as possible, and to this there is not the slightest doubt that the best remedy is *p* *manganate of potash.*

This should be used in strong solution, and not as a solid, as t liquid penetrates better into the interstices of the wound, whi should be well washed with it. For carrying out this treatment most useful little case has been devised containing a little lancet f making the wound, and permanganate crystals for making a sol tion. This little case only costs a few pence, and can be carri without any inconvenience in the waistcoat pocket, and therefo should be carried by everyone in countries where poisonous snak abound, especially when on business or pleasure in jungles or gras places. Should there be no water available to make a solutio then the crystals can be rubbed into the wound.

If the bite is on the head or trunk, the incision should be ma as above, and the resulting wound thoroughly soaked with pe manganate of potash solution (3 per cent.). The subcutaneo tissue must be freely opened, otherwise the permanganate may prevented from doing its work properly.

The after-treatment should be boric fomentations, frequent repeated at first ; but if there is no marked swelling of the part, the may be gradually, not quickly, diminished in number, and finally mild antiseptic dressing should be applied until the wound heals.

2. **Neutralization of the Poison in the System.**—We have alread endeavoured to impress on the reader the following facts :

(1) The specificity of snake-venom.

(2) The inutility of an antiserum prepared for one venom again another venom.

It now remains to consider these subjects from a practical point view.

The serum most readily obtained is Calmette's, in 20 c.c. an 50 c.c. phials standardized against cobra and *Vipera russell* venoms, and prepared by the immunization of horses against the venoms, as well as those of *Bungarus* (krait) and *Enhydrina* (se snake). Reliable sera are also prepared by the Indian Paste Institute of Kasauli for the venoms of the cobra and Russell's vipe

All these sera, unfortunately, deteriorate quickly unless kept a dark and cool place, and, further, must be used in large dose for even when fresh, 1 c.c. will only neutralize 1 milligramme cobra-venom. A healthy cobra when it bites may inject from 250 to 350 milligrammes of venom, of which the minimum lethal dose may be estimated at 15 to 17·5 milligrammes for a person weighing 60 to 70 kilogrammes; therefore at least 350 c.c. of the antivenene must be injected intravenously, or ten to twenty times that amount must be injected subcutaneously—*i.e.*, from 3,500 to 7,000 c.c.

The antivenene, of course, will succeed in much smaller doses if a small quantity of venom has been injected, and will fail if the quantity be large. Therefore the obvious indication is to begin with 100 c.c. of antivenene, injected hypodermically or far better intravenously, and to repeat this several times if necessary. The technique for the intravenous injection is as follows:

An all-glass syringe should be carefully sterilized by boiling, and the skin over the vein must be cleansed with 1 in 40 carbolic and with absolute alcohol; a band should be tied round the arm, so that the vein shows up clearly, and the needle should be inserted with the aperture pointing proximally—*i.e.*, towards the heart—and should be felt free in the vein. The ligature should then be removed and the serum slowly injected. On removal of the needle, an antiseptic pad and bandage should be applied.

If, on the other hand, the species of snake which inflicted the wound is known, and the particular serum for that animal's venom happens to be available in good condition, then it should be used intravenously.

3. **Treatment of Special Symptoms**—(1) *Failure of the Respiration.*—The experiments of Fayrer, Brunton, and Rogers seem to indicate that in cases of poisoning due to cobra and sea-snake venoms artificial respiration should be resorted to when natural respiration is failing and medical aid or remedies are being sent for.

(2) *Failure of Circulation.*—In poisoning due to viper-venoms, which produce, according to Rogers, a paralysis of the central vasomotor centre, he recommends that—

(*a*) A binder should be applied to the abdomen and bandages to the legs, so that as much blood as possible may be available for maintaining the circulation of the brain and medulla.

(*b*) That hypodermic injections of adrenalin be used to constrict the peripheral vessels and to stimulate the vasomotor centre.

In both colubrine and viperine poisons it is obvious that the circulation should also be maintained by the applications of warmth by stimulants, either alcoholic or ammoniacal, or by strychnine hypodermically.

Summary.—1. Apply proximal ligature.

2. Freely open the cellular tissue in the vicinity of the bite.

3. Wash the wound well with a strong solution of permanganate of potash (3 per cent.), or apply crystals.

4. Inject 100 c.c. of fresh antivenene intravenously.

5. Artificial respiration, if necessary.

6. Keep up the circulation by binders to abdomen, bandages to legs, stimulants, and hypodermics of strychnine.

Other Methods of Treatment.

Other methods of treatment which may be briefly mentioned are:—

Snake-Stones.—The cure which is strongly believed in by the native is t
snake-stones. These are smooth, highly polished, very light, black bodi
said to consist of calcined animal bone soaked several times with blood, a
calcined after each soaking. It is easy to understand that these stones a
very hygroscopic, and when applied to a wound, cling tightly, and suck
fluids, and perhaps some poison. There are supposed to be three kinds
stones: (1) Those composed of burnt bone; (2) those composed of chal
(3) those composed of burnt vegetal substance. Of these three only the fi
is considered of value.

The method of use is as follows: Puncture the wounds of the snake-bi
slightly, and apply the stone, which adheres, for about two minutes, a
should then drop off into a vessel of water, after which it should be dried
a cloth, and applied again to the wound, when it will adhere for about
minute. It should be applied a third time. During application the lin
should be rubbed towards the stone. The stones are used principally in Ind
and Ceylon, but they are also known in Mexico as 'piedra ponsona.' It
hardly necessary to say that from the days of Redi it has been shown h
useless these stones are.

Exorcism of the poison by shouting charmed verses is used in Indi
Numerous plants, seeds, earth moistened with urine, etc., have been extoll
as cures.

Ammonia.—Of all the old remedies ammonia has lived the longest, and
is almost incredible that Fontana settled the question as to its lack of utili
by his experiments on vipers more than 130 years ago. Whether given
the mouth, injected subcutaneously, or into a vein, it is useless, except as
stimulant, when it is certainly of no more use than alcohol. Fayrer has sho
that if liquor ammoniæ is mixed in more than equal parts with venom, it d
not destroy the poison.

Oils.—It is extraordinary how the remedies of the Middle Ages are clu
to, and oil is still used, though known to be useless since the days
Morgagni.

Strychnine.—Many years ago Duncan recommended strychnine as a reme
for East Indian snake-bites. Recently Müller of Victoria, Australia, h
strongly recommended the hypodermic injection of this drug. He says th
never less than $\frac{1}{10}$ grain is to be used, and this must be increased in urge
cases to $\frac{1}{6}$ or $\frac{1}{4}$, and repeated every fifteen or twenty minutes, until the sym
toms of snake-poisoning are removed. If a fang has perforated a vein,
recommends intravenous injection instead of subcutaneous. The patient m
be watched for twenty-four hours after the disappearance of the last sympto
in order to combat a sudden relapse. Colonel Duke, in 1895, highly reco
mends this remedy.

Arsenic.—Arsenic is principally famous as the Tanjore pill, which was s
to contain white arsenic and many other substances, but is quite useless.

Iodine.—Brainard's remedy was the injection of a solution of 10 grains
iodine and 30 grains of iodide of potassium, dissolved in 1 ounce of water, a
probably owed its reputation to its caustic action.

Bromine was at one time considered a specific.

Caustics.—Fontana strongly advised caustics, which he considered to
useful, but long experience has shown their inutility.

Stimulants.—Brandy and whisky have been repeatedly vaunted, and so h
sinapisms, warmth to the precordial region, and electricity along the spi
but all these are useless.

Energetic Movements.—Energetic movements, such as walking the pati
about, flogging him, pinching him, have been advised, but are con
indicated, as tending to exhaustion and to hasten the end.

Prophylaxis.

In the tropics Europeans and better-class Natives seldom su from snake-bite, because they do not sleep on the ground, the open or in small huts, like the lower-class Native. Among latter, however, any prophylaxis is difficult in regions such as In because they reverence the cobra, and encourage it to take up abode in their huts.

Gardens should be kept free from jungle or long grass, and grati should be placed on the drains from bath-rooms, as snakes h often been found in these rooms.

Good strong boots and the puttee pattern of legging should worn when going shooting or into the jungle. A lantern sho be used when walking after dark, and the small permanganate c already mentioned should be carried in the waistcoat pocket in c of accidents.

LACERTILIA.

FAMILY HELODERMATIDÆ.

In the Lacertilia there are two rather celebrated lizards—*Helode horridum* Wiegmann and *H. suspectum* Cope — which were placed Sumichrast in the family Varanidæ, and though this may be disputed, s it is probable that they are allied closely to that family.

Heloderma horridum Wiegm., 1834.

Synonym.—*Trachyderma horridum* Wiegm., 1829.

This lizard lives exclusively in Mexico in the hot zone which extends fr the western slope of the Cordilleras to the Pacific. It inhabits the hot, districts of Jamiltepec, Juchitan, and Tehuantepec, where it lives in h dug at the roots of trees or under vegetable débris. It is called ' escorpi by the Creoles, and ' tala-chini ' by the Zapotec Indians ; and in 1651 H nandez says it was called ' acastetepon ' by the Mexicans.

When irritated, there escapes from its mouth a white, glutinous fluid, wh is secreted by the large salivary glands. Its bite is much dreaded by natives, who say that ill-effects are produced thereby and by eating its fl It may reach to a length of nearly five feet when old. We are not awar observations on the bite or venom of this reptile.

Heloderma suspectum Cope, 1869.

Cope gave the lizard the name *suspectum*, because he suspected t its bite would be found to be poisonous. This lizard is found in the Uni States—in Arizona, Texas, Utah, New Mexico, and Southern California—wh it is called the ' glia monster.' The poison apparatus consists of gla under the lower jaw and teeth in that jaw.

The poison gland in this species lies on either side of the lower jaw, from its mesial aspect four ducts pass upwards, each towards its opening the outer surface of the mandible, through which it passes obliquely upwa and inwards, to end at the base of a tooth near the termination of a groove

The upper teeth are also grooved, but Schufeldt failed to find any gl wherewith they could be supplied with poison.

There appears to be no doubt as to the poisonous nature of the secret from the glands above mentioned, for Bonberger records that a bite in leg of a guinea-pig caused convulsions and death in three minutes.

Venom.—The venom was obtained by Mitchell and Reichert by mak the lizard bite a saucer. It was found to be alkaline, with a weak smell, an to kill frogs, pigeons, and rabbits.

The effects of glia poison have been most carefully investigated by We Mitchell and Reichert, and by Van Denburgh and Wight.

The latter consider that it differs in no important respect from snak venoms, causing death by acting directly upon the respiratory centre in th medulla, and causing paralysis of respiration. Its other actions are to fir stimulate and then paralyze the heart by poisoning its muscular fibre On inoculation, there is an immediate great fall of blood-pressure, but wheth this is due to action on the vasomotor centre or not is not clearly know There is a secondary gradual fall due to cardiac failure. The motor nerv and cells are not affected, but the sensory apparatus is at first rendered mo irritable and then paralyzed. Coagulation of the blood is at first accelerate and then retarded, so that it may become incoagulable. Hæmolysis ma occur. Local signs are almost nil, as a rule a little œdema and slight extrava sation being present.

Symptoms.—Very severe pains radiating from the part, rapid swellin faintness, profuse perspiration, may be noted.

Treatment.—A proximal ligature should be applied if on a limb, an permanganate of potash, 1-3 in 100, should be used to bathe the wound, whic finally, should be dressed aseptically.

Lanthonotus borneensis.

This lizard, which is closely allied to *Heloderma*, is suspected of bein poisonous, but there are as yet no proofs of this. Its habitat is Borneo.

MAMMALIA.

The bites of many mammals, including that of man himself, are known t produce very severe inflammation, probably because of micro-organisn introduced at the time of the injury. Excluding these, there are two mamma suspected of causing poisoning—viz., *Ornithorhynchus paradoxus*, belongin to the Monotremata, and the other the rat, belonging to the rodents.

MONOTREMATA.

Ornithorhynchus paradoxus.

As is well known, the males of this animal, which is only found in Australi have large spurs projecting backwards from their hind limbs. These spurs a hollow, and into them open the ducts of poison glands. The venom is a albuminous fluid containing albumoses.

Injected subcutaneously, it only causes local swelling, and the anim recovers in a few days. Injected intravenously, it causes fall in the bloo pressure and death from respiratory failure. The heart appears to be u affected, but the blood in the venous system is found coagulated after deat which takes place in twenty-five to thirty minutes. The venom has n hæmolytic or proteolytic action.

The difference between the slight effect of the subcutaneous and the serio effect of the intravenous injection is thought to be due to the fact that t poison is but slowly absorbed.

In a man who was stung on the hand the symptoms were very severe pai swelling in the hand, which rapidly spread up the arm, difficulty in openi the mouth, cold sweats, with severe sickness. Recovery took place in few days as far as the general symptoms were concerned, but it was sever weeks before the hand quite recovered.

The treatment has generally been ammonia, but the symptoms and t experiments point to a venom closely related to viperine poison, and should recommend the proximal ligature and permanganate of potash— fact, the treatment advocated for snake-bite.

RAT-BITE DISEASE.

Rat-bite disease is a fever characterized by a purple papular eruption, and many recurrences, said to be caused by a rat-bite.

Rat-bite disease is mentioned in Japanese medical books from the most ancient times, but it was not until Miyake, in 1901, reported eleven cases that any interest has been taken in the complaint. Since that date, according to Hara, twenty-one investigators have reported some thirty cases.

It is said to occur in all the four principal islands of Japan, but apparently only in certain districts. It is attributed to the bite of a rat which is believed to be diseased. In Ceylon there is a curious belief that if a person is bitten by a male rat in the breeding season, leprosy will result. The case which is reported by Hara is said to have been started by the bite of a female rat which was suckling its young at the time when the bite occurred. It has been said that the bite of a weasel can cause the disease, and it is known that weasels kill rats; therefore the observation indicates that the disease may be due to some animal or vegetal poison passed from the rat to the weasel.

The incubation is said to be from one to three weeks. Hara's case was ten days. The wound heals during the incubation period, at the end of which the illness begins abruptly, the site of the bite becoming red and swollen, and dropsy appearing, which spreads over the whole body. Local gangrene may occur. At the onset there is chilliness, which may amount to rigors with fever, and an eruption of purple spots on the body. Pain is felt in the abdomen, and diarrhœa may set in. Palpitations and shortness of breath may be complained of, and weakness and even delirium occur, and paralysis of the arms and legs may also be noted. Convalescence is prolonged. In Hara's case the patient was ten days unconscious, one hundred days before she was able to sit up in bed, and three years before she returned to her ordinary health. The peculiarity of this disease is its relapses, which may take place several times a year. Thus, Hara's case had about ten relapses a year for a period of seventeen years. The blood shows nothing abnormal in its red or white cells.

Three different types of this disease are described: a febrile type with a marked eruption, a febrile type with nervous symptoms, and an abortive type; but the first is the most common.

The history of the rat-bite taking place in Japan, together with the history of a relapsing fever with long intervals, and the presence of the purple-coloured eruption, ought to enable the diagnosis to be made without difficulty.

The prognosis is usually good. The mortality, based upon thirty-eight cases, is said to be 10·5 per cent. Death is caused by collapse, or blood-poisoning in the first attack.

The only changes found post mortem are hyperæmia of the pia mater of the spinal cord, and an increase in the cerebro-spinal fluid.

No special treatment is recommended. Thorough disinfection of the wound as soon after infection as possible is advised as a prophylactic remedy. The popular method in Japan is, or was, to cook and eat the rat which inflicted the bite.

If the history detailed above represents a separate disease due to the bite of a rat, it must be caused by some animal or vegetal parasite introduced into the wound, but at present there is no proof of this.

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SECTION C

BIOLOGICAL CAUSES OF DISEASE

CHAPTER XI

ANIMAL PARASITES

Biological causes of disease—Animal parasites — Protozoa — Sarcodina — Mastigophora.

In tropical medicine the important biological causes of disease are the parasites, which may be classified into—A. Animal Parasites; B. Vegetal Parasites.

ANIMAL PARASITES.

Definition.—A parasite is defined to be a living organism, animal or vegetal, which takes up its abode temporarily or permanently on or within other living organisms (called the hosts) for the purpose of obtaining food.

Animal parasites (zooparasites), in the process of obtaining this food, may cause disease by their mechanical action and chemical products, or by introducing into the host pathogenic micro-organisms.

As examples of the latter may be mentioned the transmission of the animal organism which causes malaria by certain members of a family of the mosquitoes, or that of the vegetal organism which is the cause of plague by certain fleas. Intestinal worms probably cause many of the symptoms of the disease with which they are associated by the introduction into the body of poisons through their bites, or, according to Sambon, by their active migrations before attaining maturity and reaching their selective anatomical habitat.

A well-known example of the irritation caused by the introduction of chemical poisons is the ordinary mosquito-bite already described, while *Trichinella spiralis* produces violent disturbance while wandering through the body.

Mechanically the jigger (*Dermatophilus penetrans*) causes much irritation to the foot, and *Filaria loa* to the eye.

Animals may be only '*temporary parasites*'—*i.e.*, they only temporarily affect the host, as, for example, mosquitoes—or they may be '*stationary parasites,*' such as the malarial organism whi lives in the red cells of the blood. These latter may be subdivid into 'periodical parasites,' which only spend a portion of their li history within a host, and 'permanent,' which are parasitic throug out the whole life cycle. As an example of the former may mentioned the larvæ of certain flies which are parasitic, while the f itself is not, and of the latter *Oxyuris vermicularis* is a good exampl

Animal parasites may be classified in *ectoparasites* or *epizo* affecting the skin and exterior of the host; and *endoparasites* *entozoa*, affecting the internal organs or cavities of the host.

Until recent years the greatest confusion existed as to t nature of parasites. With our present knowledge it appea that parasites, however altered in structure some of them ma have become during their parasitic existence, have been originall derived from free-living forms. It will, however, be noted that the are great differences in the structure and appearance between som of the permanent parasites and their nearest free-living affinitie This difference has been brought about mainly by environment.

The permanent parasite, particularly if an entozoon, has foo prepared for it by its host in an easily assimilated form; hence the is no necessity for a complicated digestive apparatus, which in certa cases has entirely disappeared.

Further, certain parasites, having reached an organ which suppli them with suitable food, do not require organs of locomotion, f they have only to remain where they are, and the tissues of t host will subserve their purpose. Some of them have no necessit as a rule for locomotion for sexual purposes, because hermaphr ditism is common, and even in cases where this is not foun parasites often live in couples (male and female).

Being enclosed in the body of the host, there is no necessity f sense organs; therefore these are much reduced, or are absent.

On the other hand, the parasite requires something to enable to fix itself firmly to the tissues of the host; hence suckers and hook are often found, and also clasping and clinging organs.

The chance of a parasite, locked up inside a host, successfully r producing its species is small; hence reproduction assumes importan features associated with the production of large numbers of ne forms, which are often protected by shells or other coverings.

Reproduction may be asexual, especially in the protozoa, or sexua Sexual reproduction in parasites is generally complicated, endin in the production of large quantities of eggs or spores; and ver often the spores of the protozoa or the corresponding larval form of the metazoa may travel through one or more intermediary host before they infect another definitive host—that is, one in whic the sexual life-history is gone through.

With regard to the sexual process, it may be noted that often th male is smaller than the female, and in fewer numbers, but ther are exceptions.

Usually parasites keep strictly to certain hosts called 'norma hosts,' but at times they are found in unusual hosts—for exampl *Echinorhynchus gigas*, which is usually found in pigs, may infe(man. Such a parasite is called a 'chance parasite,' while objec mistaken for parasites are known as 'pseudoparasites.'

The above are examples of simple parasitism; but there are par sites which are parasitic upon other parasites—a condition calle 'hyperparasitism.' These hyperparasites may be secondar tertiary, or quaternary, and their importance in disease has bee emphasized by Sambon, who has shown that it may be one of th causes of the disappearance of malaria from a district, for th black spores found by Ross in mosquitoes infected with malaria a now known to be hyperparasites of the genus *Nosema*.

For further remarks see the article on Metazoan Parasites.

Nomenclature.

Medical men in the tropics are at present almost daily discovering new, (what are thought to be new, parasites, and are generally desirous of givir them definite names, but before doing so it behoves the discoverer to kno and obey the international code laid down by zoologists, for which purpo they should study Stiles' pamphlet in the bulletins of the United Stat Public Health and Marine Hospitals Service.

Four rules may be mentioned here:

1. **Language Rule.**—The name given to the parasite must be in Latin, an not in any vernacular.
2. **Rule of Priority.**—The valid name for a genus or species is the olde available name. Therefore, in describing a species or genus, give not merel the name of the authority who invented the term, but the date also.
3. **Rule of Homonyms.**—When two distinct genera or species of anima receive the same name, that applied earliest alone must stand.
4. **Rule of Appropriateness.**—No name is allowed to be changed simpl because it is inappropriate.

With regard to disease there is no fixed rule, but we feel sure that if medic men would follow the zoologists, and evolve a fixed method of nomenclatur much confusion would be avoided.

When an animal parasite causes a series of symptoms in a man or a animal, it is usual to name the affection by that of the animal causing th disease, together with the suffix 'iasis.' Thus, *Entamœba histolytica* caus amœbic dysentery and liver abscess, etc., which might be classed togeth under the term 'Entamœbiasis'; or *Paragonimus westermani* causes a vari number of symptoms, which can all be classed together as 'Paragonimiasis.

The animals which cause and convey disease in man may b classified into the following subkingdoms: Subkingdom I., Protozoa Subkingdom II., Metozoa.

SUBKINGDOM I. PROTOZOA.

Definition.—Protozoa are unicellular animals, solitary or unite into colonies, free living or parasitic, with asexual reproductio (schizogony) by binary fission, budding or fragmentation and sexu reproduction (sporogony), or merely rejuvenescence by conjugatio

The border-line between unicellular animals and unicellular plant is very vague, and hence at present it is uncertain whether som forms should be classed with the bacteria and considered to be plant or with the protozoa and considered to be animals.

Phylogenesis.—There can be little doubt that the primitive for of protozoon must have been an animal with some of the chara teristics of the amœba, and would most likely be free-livin most probably in water. This simple form, taken into the alime tary canal of higher animals, possibly benefited by the ease wit which food was obtained and by the protection afforded by t new position, and thus became modified to suit its environmen The most important modification would be some protection for t earliest stages of its life-history, which would enable it to live i the outside world until taken up by a suitable host, and associate with this would be the necessity to produce large numbers of suc protected spores, as the chance of one finding a suitable host mus be relatively small. Such a type would be represented by th *Entamœba coli* Lösch, which is a parasite of man. Such a parasit may cause no harm to its host, which is fairly indifferent to it existence. On the other hand, a parasite may not find sufficien nutriment in the alimentary canal, and be compelled to seek bette food, and perhaps more protection, by entering the glands c Lieberkühn, or even the submucosa of the bowel. Such a parasit might cause disease in its host, and would be illustrated by th *Entamœba histolytica* Schaudinn of man.

Such a process, however, took place not merely in man, but i many other kinds of animals, among which may be mentione insects, in the alimentary canal, of many of which protozoan parasites are found. In these insects the sexual process takes place, an therefore they are the definitive hosts, and may also be considere the primary hosts.

If these primary hosts become predatory, biting and sucking th blood of other animals—*e.g.*, vertebrates—then, during this proces they might pass the spores of their parasites into the blood of th vertebrata, and if these are not killed off (for some animals ar repellent) by chemical substances, or destroyed by leucocytes, the might develop in the blood of some vertebrate (called tolerant) which thus becomes the secondary host.

It is, of course, possible that some of these blood protozoa ma have been derived from parasites originally intestinal in the vertebrate, which found their way not merely into the mucosa of th bowel, but later into the blood-stream, in which they would b fairly well protected, and from which they would at first escap by becoming encysted in the intestinal wall, and then, bursting int the bowel, make their way to the exterior with the fæcal matte and so infect a new host. When blood-sucking animals becam evolved, a new cycle would be open for them—viz., from th vertebrate through the blood-sucker back to the vertebrate—an thus the old method by way of the alimentary canal would be lost

The origin of the protozoan blood-parasites of man may therefor be twofold: (*a*) from man's intestine into the blood; (*b*) from a invertebrate's alimentary canal into the blood of man.

The result of one or other of these methods is well illustrated b the malarial parasite, which passes through its sexual cycle in an *Anopheline* mosquito, which is its definitive and, according to the view adopted, its primary or secondary host. When the infected *Anopheline* bites a man, the parasite enters into the blood-stream, in the red cells of which it develops and undergoes its asexual cycle. Man is therefore the intermediary, and either the primary or secondary, host of the malarial parasite, as mentioned above.

The blood-stream of man contains two different elements:—(1) liquor sanguinis; (2) cells—(*a*) red, (*b*) white. Therefore the parasite has two possibilities before it—either to live in the liquor or in a cell, or partially in one and partially in the other; and this last is what generally happens—*i.e.*, the parasite lives so much of its cycle in a cell and so much in the blood-stream. It would, however, appear that there is a great phylogenetic tendency for protozoan parasites to leave the liquor sanguinis and to reside in red cells (the malarial parasite) or in white cells or in endothelial cells (the Leishman-Donovan parasite),

Infection of the Embryo.—Protozoan blood parasites apparently can be arranged in two categories as regards the infection of the fœtus, for some, like the malarial parasite (which is generally considered to be incapable), do not traverse the placenta, while others, like the *Spirochætes* and *Treponemata*, can do so. With regard to the infection of invertebrate eggs the matter is quite different, for many of these parasites infect the eggs, thus carrying the germs of disease into a new generation of blood-suckers.

It would appear as though the intracellular stage enabled the parasite to grow (*e.g.*, consider Schaudinn's history of the development of *Hæmoproteus noctuæ* in the little owl) and to multiply (*e.g.*, note the development and multiplication of the malarial parasite).

In the evolution of such hæmatozoan types some authorities (Woodcock) hold that the flagellate forms living in the blood-stream are to be considered the most primitive, and that the more truly cellular the parasite becomes, the more it has evolved. Hence the *Hæmoflagellata*, or parasites freely moving in the liquor sanguinis, are with difficulty separated from the *Hæmosporidia*, or parasites which mostly live in blood cells. For many reasons some of these two groups of parasites have been united together into one order of the flagellates, as will be explained further on.

General Account.—Protozoan parasites vary in size from the large *Sarcocystidæ* in muscle to most minute forms in the blood (*Hæmoprotozoa*). In fact, it is possible that some forms may exist which we have not yet recognized, because their minute size prevents their being visible to the human eye, even when aided by the highest powers of the microscope.

The parasites themselves consist of protoplasm, which in some instances shows a modification into ectoplasm and endoplasm, the former being clear and hyaline and the latter dark and granular.

In the protoplasm are to be found—(1) nucleus, (2) metaplasmat granules, and (3) vacuoli.

The nucleus is a complex body composed of chromatic an achromatic substances. It may be single, or divided into tw principal masses—trophonucleus or nutrition-nucleus and kinet nucleus or motion-nucleus, or into macronucleus and micronucleu The latter are quite different from the tropho- and kinetonuclei, f the macronucleus is trophic and kinetic, while the micronucleus

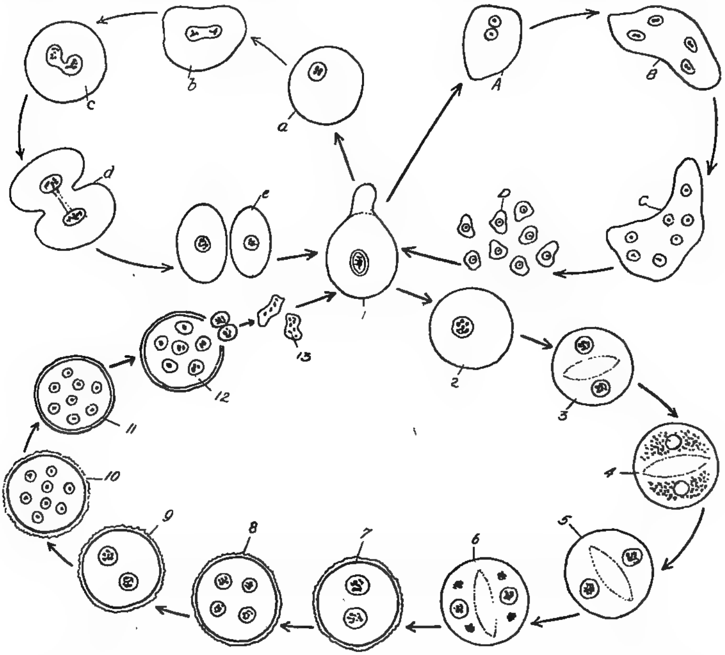

FIG. 38.—DIAGRAM OF THE LIFE-CYCLES OF ENTAMŒBA COLI LOESCH.

1, *Entamœba coli* ; *a-e*, stages in the process of binary fission ; A-D, frag mentation or schizogony ; 2-13, sexual reproduction or sporogony.

purely reproductive. The former are typically seen in the binucleat and the latter in the heterokaryota.

Associated with the nucleus may be found small granules chromatin scattered through the cytoplasm. The metaplasti granules are metabolic products. The vacuoli may be either th contractile vacuole, which is considered to be respiratory an excretory in function, or the food vacuoles, which begin with globule of water taken in with the food. Into this vacuole an aci is secreted from the cytoplasm and digests the food, which is the absorbed. Then the vacuole with the undigested food travels t the periphery, and the waste product is extruded.

Protozoa generally have some power of movement by pseudopodia, cilia, or flagella, but under unfavourable circumstances they may lose this power, and, becoming quiescent, surround themselves with an envelope and become encysted. Unfavourable circumstances are lack of food, desiccation, irritating chemical substances, and unusual surroundings.

Reproduction in the protozoa takes place asexually or sexually. As long as conditions are favourable—*i.e.*, there is abundance of food—protozoa reproduce asexually by one of the following methods: (1) binary fission; (2) gemmation; and (3) spore-formation.

1. *Binary Fission.*—In binary fission there is first division of the nucleus, which sometimes takes place by amitosis, followed by that of the cytoplasm, when the parasite divides into two more or less equal halves (Fig. 38).

2. *Gemmation.*—In gemmation the nucleus divides usually by mitosis into two or more nuclei, which either travel to the periphery, and become surrounded by small masses of protoplasm, which separate from the parent parasite—ectogenous gemmation—or remain in the cytoplasm, a portion of which becomes differentiated around each nucleus—endogenous gemmation.

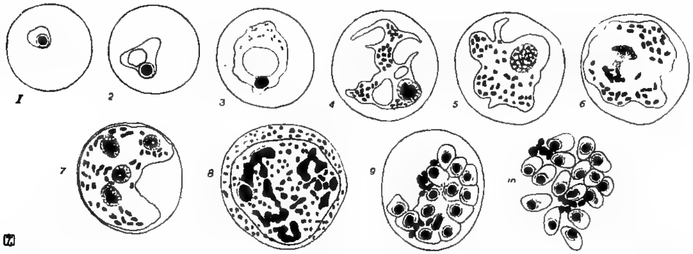

Fig. 39.—Schizogony of Plasmodium vivax Grassi and Feletti.

(After Schaudinn.)

1, Young trophozoite; 2, ring form; 3, ring form showing hæmozoin; 4, parasite with pseudopodia; 5, old trophozoite; 6, schizont showing commencement of first division; 7, schizont with four nuclei; 8, schizont with several nuclei (the corpuscle shows Schüffner's dots); 9, schizont divided into merozoites; 10, merozoites and hæmozoin free.

The explanation of the two methods is that in ectogenous gemmation the buds are separated from the mother cell externally, while in endogenous gemmation the localized budding area sinks into the body substance of the mother cell, with the result that the buds are contained in a brood sac. This localized endogenous area is called a pansporoblast, though in some the entire organism forms a pansporoblast, which is considered to be phylogenetically derived from the localized condition—*i.e.*, the whole cell represents only the pansporoblast.

Plasmotomy.—Plasmotomy is the term applied to the intermediate division of the cytoplasm of multinuclear parasites into two or more masses, which afterwards may or may not reprodu by spore-formation.

3. *Spore-Formation.*—Instead of being considered a process internal gemmation, the formation of pansporoblasts may looked upon as a process of spore-formation proceeding while th organism grows, as is typically seen in the Neosporidia.

The typical asexual spore-formation or schizogony is, howeve met with in the Binucleata and Telosporidia, in which the earl stages absorb nutriment and increase in size, being therefore calle trophozoites. When fully grown they form a quiescent body, th schizont, whose nucleus and cytoplasm divide into a number small forms called asexual spores or merozoites, generally, how ever, leaving a little undivided cytoplasm laden with effete matte which is called a *nucleus de reliquat*, or ' rest body.'

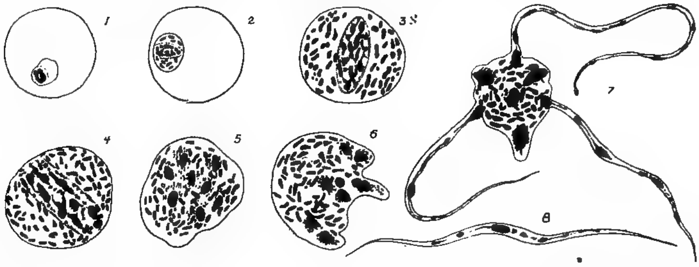

Fig. 40.—Sporogony of Plasmodium vivax Grassi and Feletti. Development of the Microgamete.

(After Schaudinn.)

1, Young microgametocyte; 2, 3, older forms; 4, fully-grown microgamet cyte, as seen in the blood of man; 5, division of the nucleus (reduction) in th stomach of an anopheline; 6, nuclei have travelled to the periphery, which ha grown out to form the commencement of a microgamete; 7, microgametocyt with three microgametes; 8, a free microgamete.

These merozoites are the forms by which the parasite multipli in the given host, and are not the means by which new hosts ar infected. They therefore enter new cells in the host in whic they are formed, and growing into a trophozoite, complete a asexual life cycle, which is called the cycle of schizogony, o simply schizogony (Fig. 39).

A time arrives in the infection of every host when the foo material for the given parasite is diminished by the numbers forms produced by asexual reproduction, or when the tissues of th host react against the parasite by chemical substances, or phag cytosis, or by both methods combined.

When these adverse circumstances become sufficiently sever changes take place in the parasite which produce forms capable leaving the given host and existing outside it, either in a differe species of animal or simply in the exterior, until an entry is ma into a new host of the same species as before, when schizogony begins again.

The changes which the parasite has to undergo in spreading from one host to another are generally associated with sexual reproduction, and the whole cycle from a given host of a certain species to another host of the same species is called the cycle of sporogony, or, more simply, sporogony (Figs. 40, 41, and 42).

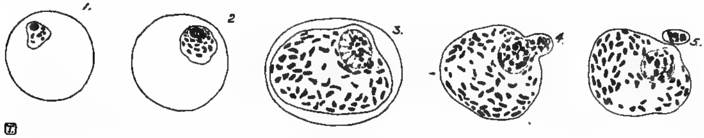

FIG. 41.—SPOROGONY OF PLASMODIUM VIVAX GRASSI AND FELETTI. DEVELOPMENT OF THE MACROGAMETE.

(After Schaudinn.)

1-3, Young macrogametocytes; 3, Fully-developed macrogametocyte in the blood of man; 4, reduction and formation of a polar body in the stomach of an anopheline mosquito; 5, macrogamete and one polar body.

In adverse or changed circumstances, therefore, the merozoites develop into more resisting forms, which are called gametocytes, in which, by reduction of the nuclear material, the male and female elements in the nucleus are separated; the two elements may exist in the same cell or in separate sells, but usually the male element of one cell fuses (zygosis) with the female element of another cell, and forms a new individual with a new nucleus or synkaryon.

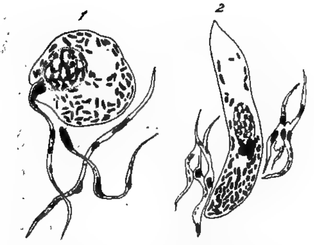

FIG. 42.—SPOROGONY OF PLASMODIUM VIVAX GRASSI AND FELETTI: ZYGOSIS.

(After Schaudinn.)

1, Zygosis of one microgamete with the macrogamete; 2, oökinete and degenerate microgametes.

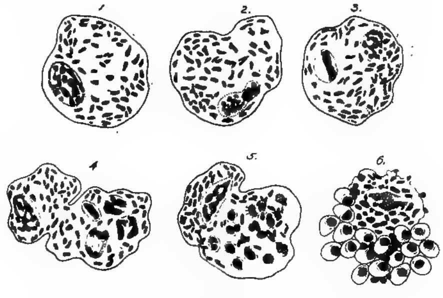

FIG. 43.—PARTHENOGENESIS OF PLASMODIUM VIVAX GRASSI AND FELETTI.

(After Schaudinn.)

1, Macrogametocyte; 2, division of the nucleus; 3-6, formation of merozoites from one portion of the nucleus, and separation of the other portion with the hæmozoin.

This new individual proceeds to reproduce itself rapidly by either binary fission or spore-formation. In the latter case, in order to prevent confusion, the terms employed are different fro those used in asexual reproduction. The parasite is called sporont, the spores sporozoites. The sexual reproduction tak place in the definitive host, which may be different from the inte mediary host in which the asexual reproduction is found.

Parthenogenesis and Etheogenesis.—In addition to the abov reproduction can take place from a female type of parasite (parthen genesis), or more rarely from a male type of parasite (etheogenesis without any completion of the sexual process (Fig. 43).

A very good example of parthenogenesis is found in the malari parasite, in which the female gametocyte is capable of resistin both the action of the chemicals of the body and drugs, and therefore capable of lying dormant for some time. When given a opportunity for development, its nucleus and protoplasm divid into two portions, one of which degenerates and disappears, whil the other forms merozoites and starts the cycle of schizogony ane

Etheogenesis, a term introduced by Prowazek, is the much rar change in the male parasite whereby asexual reproduction begi again.

Classification.—The classification of the subkingdom protozo is by no means satisfactory at present, and will have to be co siderably altered in the near future.

The usual classification is into four phyla: (1) sarcodina; (2) mas tigophora; (3) sporozoa; (4) infusoria.

The sarcodina move and capture food by pseudopodia; th mastigophora by flagella; the sporozoa are parasites withou motile organs; and the infusoria move by means of cilia. Whe this classification was brought into use, practically nothing wa known about the life-history of the protozoa, a more complete know ledge of which is still required.

Since the valuable researches of Schaudinn into the life-historie of some flagellates, suspicion has been aroused that some of th Hæmosporidia are stages in the life-history of the Hæmoflagellata.

Even if this be not correct, there is evidence of a close relatio ship between the two groups, and there are biologists who believ them to be phylogenetically related.

Therefore Sambon 1906 and Hartmann 1907 have united th Hæmoflagellata and the Hæmosporidia into one group, whic belongs to the flagellate division of the protozoa, an arrangeme which we have partially followed, for recent researches indicat that the Hæmogregarines are allied to the Telosporidia.

Among the blood parasites of man and other animals there a found some wavy, thread-like organisms (*Spirochætes* and *Tr ponemata*), with which must be classed some free-living forms who position, even in the animal kingdom, has been disputed.

The opinion is gaining ground, however, that these forms a protozoa with a low type of nucleus, but so different are they fro the ordinary phyla of protozoa that, following Doflein's an Fantham's suggestions, we shall place them in a separate phylu hough Calkins thinks it better to leave them in their old position t present.

Further, the old group of the sporozoa contains two such different roups of animals in its subdivisions into Telosporidia and Neoporidia that it is justifiable to do away with this combination, nd to raise the two divisions to the rank of separate phyla.

Finally, the two nuclei of the infusoria are so totally different n function from the nucleus or nuclei of the rest of the protozoa hat the subkingdom is capable of being divided into two divisions —the Heterokaryota or infusoria, and the Plasmodromata, under vhich heading come the other phyla.

The classification of the protozoa will therefore be arranged as ollows :

DIVISION I. PLASMODROMATA Doflein 1901.

Protozoa in which the nucleus is not separated into reproductive (micronucleus) and non-reproductive (macronucleus) portions.

Subdivision A.—Without well-defined nucleus.

Subdivision B.—With well-defined nucleus or nuclei in some stage of the life-history.

Phylum I. Sarcodina.—Plasmodromata which move and capture their food by pseudopodia.

Phylum II. Mastigophora. — Plasmodromata which move and at times capture their food by flagella.

Phylum III. Telosporidia.—Parasitic Plasmodromata in which spore-formation is distinct from, and takes place after the trophic phase of the life cycle.

Phylum IV. Neosporidia.—Parasitic Plasmodromata in which spore-formation and trophic growth proceed simultaneously.

DIVISION II. HETEROKARYOTA Hickson 1903.

Synonym.—*Ciliophora* Doflein 1901.

Protozoa possessing cilia either throughout life or only in the early stages of the life cycle, but always with a micronucleus, which is entirely reproductive in function ; and a macronucleus, which is trophic and kinetic.

Phylum V. Ciliata.—Heterokaryota possessing cilia throughout life.

Phylum VI. Acinetaria. — Heterokaryota possessing cilia only in the early stages of the life cycle.

A most unfortunate feature with regard to classification is the fashion prevalent just now of naming as new any blood parasite found in a host in which that particular type has not been found before. The researches of Laveran and Mesnil, Negri and others, tend to show that in nature one species of parasite is not limited to one species or one genus of host ; further, that the same parasite may somewhat vary in different hosts. With these two facts in view it is quite possible that the numerous trypanosomes and hæm gregarines described in different hosts may some day be reduce in numbers when their life-history is fully known. In ord to meet this difficulty, Sambon has suggested adding a thir name—that of the host—to the nomenclature of the species these families.

PHYLUM I. SARCODINA.

As already noted, Sarcodina are protozoa moving and capturin their food by means of pseudopodia.

They are divided into three classes :

Class I. Rhizopoda.—Sarcodina, parasitic or free-living, with pseudopod in the form of lobose or reticulate processes.

Class II. Heliozoa.
Class III. Radiolaria. } Sarcodina which are never parasitic.

Class I. Rhizopoda.

The Rhizopoda are the Sarcodina which concern us, and they are divide into—

Subclass I. Amœbida.—Rhizopoda, parasitic or free-living, with lobo pseudopodia.

Subclass II. Foraminifera.—Rhizopoda which are never parasitic.

Subclass I. Amœbida.

The Amœbida are the only Rhizopoda with which we are interested, and the are classified into—

Order I. Gymnamœbida.—Naked Amœbida.
Order II. Thecamœbida.—Shell-bearing Amœbida.

ORDER I. GYMNAMŒBIDA.

This is the only order of the Sarcodina which contains parasiti forms, of which the important genera are : Genus 1. *Entamœba* Genus 2. *Paramœba* ; and Genus 3. *Leydenia* (doubtful).

Genus 1. Entamœba Casagrandi and Barbagallo 1895.

The genus *Entamœba* is separated from that of the amœba by th fact that its species are parasitic, do not contain a contractil vacuole, possess a nucleus, and when encysted, reproduce by interna division (endogeny).

A large number of these *Entamœbæ* have been described in ma

A. Intestinal.—(1) *Entamœba coli* Lösch 1875 ; (2) *E. histolytic* Schaudinn 1903 ; (3) *E. undulans* Castellani 1904 ; (4) *E. tropical* Lesage 1908 ; (5) *E. tetragena* Viereck 1907 ; (6) *E. phagocytoides.*

B. Buccal.—(7) *Entamœba gingivalis* Gros 1849 ; (8) *E. buccal* Prowazek 1904 ; (9) *E. dentalis* Grassi 1879.

C. Urogenital.—(10) *Entamœba urogenitalis* Bälz 1883.

D. Pulmonary.—(11) *Entamœba pulmonalis* Artault 1898.

E. In Abscesses.—(12) *Entamœba kartulisi* Doflein 1901.

F. In Serous Exudations.—(13) *Entamœba miurai* Ijima 1898.

In addition to these, a number of *Entamœbæ* have been described in animals—viz., *Entamœba muris* Grassi in the intestine of mice, which Wenyon considers is the same as *E. coli* Lösch of man; *E. blattæ* Bütschli in the proctodæum of *Blatta orientalis*, the cockroach; *E. ranorum* Grassi in the alimentary canal of *Rana esculenta; E. pædophthora* Caullery, attacking the eggs of a crustacean, *Peltogaster curvatus;* and *E. nuttalli* Castellani 1908 found in a liver abscess and in dysentery in monkeys in Ceylon.

It is, however, with the human *Entamœbæ* that we are concerned. The mouth amœbæ are probably all the same species as the *Entamœba buccalis* of Prowazek, though it is not possible to be quite certain whether *E. buccalis* of Sternberg 1862 really is the same.

Associated with abscesses about the lower jaw or the floor of the oral cavity, amœbæ have been described (*Entamœba kartulisi* Doflein) by Kartulis and by Flexner, which may be *E. buccalis*, or may be, as Doflein suggests, *E. histolytica*, which is well known to enter the blood-stream and be disseminated over the body, giving rise to a form of general entamœbiasis.

Bälz, Jürgens, Kartulis, Posner, and Wynhoff have described amœbæ in the urino-genital tract of man, which were very motile, 50 μ in diameter, with granular plasma and vesicular nucleus. *Amœba miurai* from the serous fluid of a woman suffering from peritonitis and pleuritis due to an endothelioma, and the amœba-like bodies described by Schaudinn under the name *Leydenia gemmipara*, appear of doubtful nature, though Lauenstein and Behla have recently recorded the same organism in a case of cancer with ascitic fluid.

This reduces the *Entamœbæ* to be considered to—*Entamœba coli* Lösch 1875; *E. histolytica* Schaudinn 1903; *E. tropicalis* Lesage 1908; *E. undulans* Castellani 1905; *E. tetragena* Viereck 1907; *E. buccalis* Prowazek 1904.

With regard to these, the greatest difficulty has been the separation of *Entamœba coli* from *E. histolytica.* The history of these amœbæ is interesting. Starting in 1859 with the note by Lambl of the presence of some sort of an amœba and other protozoa in a case of dysentery, the first clear account is that by Lösch in 1875, in which he considers these amœbæ as the cause of the dysentery.

This, however, was soon followed by Grassi's (1879) description of the amœbæ in the motions of healthy people, and in 1881 by the papers of Lewis and Cunningham concerning their presence in persons suffering from cholera. Lösch's findings were, however, confirmed by Koch and Kartulis, and since that time it has been more or less generally believed, especially after the classical investigation of Kruse and Pasquale, that there are two kinds of amœbæ, one harmless, and the other the cause of entamœbic dysentery (*e.g.*, Councilman and Lafleur, Roos, and Quincke). It was not, however, till the description of *Entamœba coli* by Casagrandi and Barbagallo and the investigations of Jürgens were compared and extended by Schaudinn that it was possible to clearly understand the difference betwee these amœbæ.

Schaudinn, however, clearly separated them into *Entamœba co* Lösch and *E. histolytica* Schaudinn, and it is from his wor that the following description is taken.

Entamœba coli Lösch 1875.

The *Entamœba coli* of Lösch may be defined as an amœba para sitic in the intestines of healthy human beings, and characterize by possessing no distinct layer of ectoplasm, unless a pseudopodiur is being formed, when a hyaline projection, which is the ectoplasr followed by endoplasm, flows out into a typical pseudopodiur which, owing to this construction, is looked upon as being sof The other characteristics are the presence of a large easily-see nucleus placed subcentrally and deeply stained by reagents, an the fact that when this divides in schizogony or sporogony eigh merozoites or sporozoites result. It varies from 8 to 50 μ in diamete

Entamœba coli lives in the lumen of the large intestine, neve penetrating the mucosa and feeding on the contents of the bowel.

Reproducton is both asexual and sexual (*vide* Fig. 38).

Asexual Reproduction.—Asexual reproduction may take plac by (*a*) binary fission, (*b*) fragmentation, which are best studie by giving infected persons a saline purgative and examining th motions microscopically.

(*a*) *Binary Fission.*—In this method the nucleus first divides b amitosis, and then the cytoplasm follows suit, and two forms resul which grow into the usual adult type.

(*b*) *Fragmentation.*—The parasite which reproduces by th method is a schizont. Its nucleus divides by mitosis into eigh nuclei, around which the protoplasm divides to form eight littl amœbæ (merozoites), which grow into adult parasites.

Sexual Reproduction.—Sexual reproduction, or sporogony, complex, and only begins when conditions for obtaining food becom less favourable—*e.g.*, when diarrhœa is passing off or in health motions—and is the method whereby the parasite is transferre from one host to another. It therefore begins in host No. 1 (man continues in the world external to that host, and concludes host No. 2 (man).

The whole process has been worked out by the researches Casagrandi and Barbagallo, confirmed and extended by Schaudin not merely by microscopical research, but also by feeding exper ments upon himself and cats.

Sporogony begins by an *Entamœba* secreting a thin gelatino envelope around itself, and then passing out of host No. 1 into t external world with his fæces. About 80 to 90 per cent. of the encysted parasites perish and undergo no further development, b some 10 to 20 per cent. proceed farther.

The first step is that the nucleus divides into two daughter nucl which travel to opposite poles of the parasite, while a clear dividing-line appears in the cytoplasm between them.

This constitutes the division of the parasite into two separate individuals.

After a pause the chromatin of these nuclei passes into the protoplasm, forming the chromidia of a diffuse nucleus, and all that remains of the original nucleus is the achromatic portion, which then disappears. A certain number of the chromidia also disappear, while the remainder collect together and form, in each half of the parasite, a new nucleus. Therefore each individual has a new nucleus. The explanation of this process is probably the separation of the vegetative from the sexual elements of the nucleus. The result, therefore, is two cells, each of which contains male and female elements, as will appear later.

The new nuclei now proceed to divide into two, and again into two, thus forming three nuclei in each portion of the cytoplasm.

Two of these are absorbed or thrown out, and therefore must be looked upon as polar bodies, and the whole process is somewhat analogous to reduction in higher animals—*i.e.*, to the maturation of the sexual elements. There is therefore left in each portion of the cytoplasm only one nucleus, and now changes begin to take place in the cyst-wall and the protoplasm. The cyst-wall becomes much thicker, while the protoplasm shrinks and the dividing-line disappears, so that the parasite consists of one mass of cytoplasm containing two bisexual nuclei. Each of these nuclei divides into two by mitosis, forming a male and a female pronucleus. The male pronuclei move across the cytoplasm and conjugate with the female pronuclei of the opposite pole, thus forming two synkarya. This process may be looked upon as analogous to the fusion of the ovum and spermatozoon of higher animals.

Each synkaryon now divides into two, and each of these again into two, so that the single mass of protoplasm now possesses eight nuclei, the whole being surrounded by a thick cyst-wall.

The parasite remains in this condition until swallowed by host No. 2. When the cyst reaches the large bowel its protoplasm quickly divides into eight little amœbæ or sporozoites, which, escaping from it, in their turn develop into adult parasites, thus completing the cycle of sporogony.

Pathogenicity.—This amœba is a harmless commensal in the alimentary canal of man.

Culture.—*Entamœba coli* Lösch has been artificially cultivated in symbiosis with bacteria, but for information on this subject see the remarks under the same heading in the description of *E. histolytica.*

Entamœba histolytica Schaudinn 1903.

This parasite has been carefully described by Jürgens in 1902, and his observations have been confirmed and much extended by Schaudinn.

When fully grown it measures about 25 to 30 μ in diameter, an has a clearly defined ectoplasm, of which the pseudopodia ar entirely composed. The pseudopodia are considered by Schaudin to be capable of burrowing into epithelial cells and into th submucosa of the bowel. He lays great stress upon this factor, a the difference between the harmless commensal *Entamœba coli* an the disease-producing *E. histolytica.* The nucleus is small in siz poor in chromatin, and placed excentrically, sometimes close to th periphery. The parasite appears to feed on detritus, bacteria, an red cells.

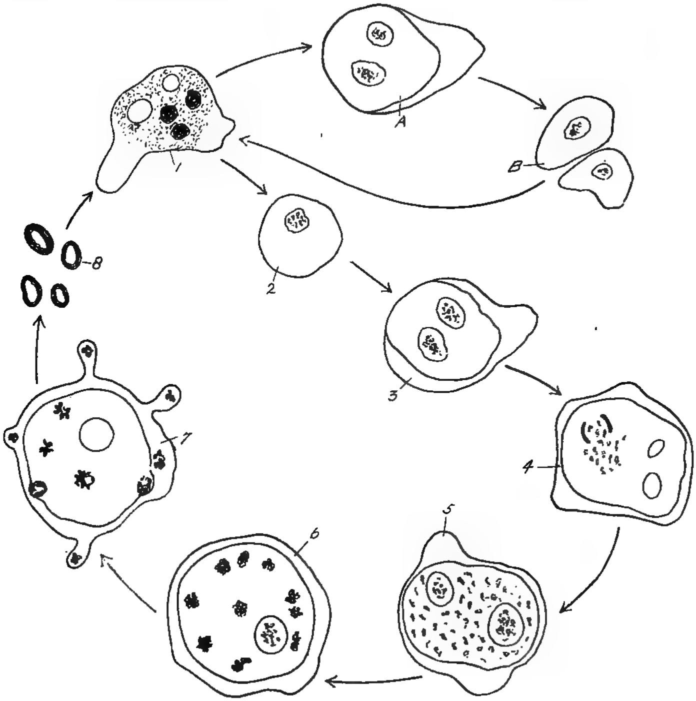

FIG. 44.—DIAGRAM OF THE LIFE-CYCLES OF ENTAMŒBA HISTOLYTICA SCHAUDINN.

(Constructed from Craig's drawings in the *Journal of Infectious Diseases.*)

A, B, Binary fission; 1-8, spore formation.

It reproduces in three ways: (1) binary fission; (2) gemmation and (3) spore-formation.

1. *Binary Fission.*—This method was only discovered by Schaudinn on examining fresh specimens of the infected alimentary cana The nucleus divides by amitosis into two, and then the cytoplasm splits into two equal daughter cells.

2. *Gemmation.*—Gemmation, found more commonly than binary fission by Schaudinn, consists of the division of the nucleus by amitosis into two or more daughter nuclei, which, together with small portions of the cytoplasm, separate off from the mother cell, the daughter cell being smaller than the mother cell.

3. *Spore-Formation.*—In spore-formation, which only takes place under unfavourable circumstances, such as when recovery is taking place after an attack of dysentery, the chromatin in and around the nucleus becomes diffused into the cytoplasm, and finally collects near the periphery, and the remains of the nucleus disappear, being either pushed out or absorbed. The ectoplasm forms small knobs, containing several chromidia in each. These knobs and their chromidia become separated off as rounded bodies, which, becoming surrounded with a yellowish-brown envelope, form the spores for the infection of a new host, as has been shown by Schaudinn's feeding experiments on cats, which developed typical dysentery with the amœbæ in the motions, in the lumen, and the wall of the alimentary canal. These experiments further proved that it was only by the spores that infection would be spread. The rest of the amœba, after the formation of the spores, dies.

Schaudinn was not able to trace the development any farther than the above sketch. Lesage says that the nucleus in the little cyst divides into three laterally-placed nuclei, each of which develops into a small amœba.

Pathogenicity.—*Entamœba histolytica* is the cause of entamœbiasis —*i.e.*, all those ailments, such as amœbic dysentery, liver abscess, abscesses in other parts of the body, in which it is found.

Culture.—*Entamœba coli* and other non-pathogenic amœbæ have been cultivated in association with bacteria in the water of condensation of various solid media. *E. histolytica* has not yet been cultivated in this way. Lately Lesage has demonstrated that leucocytes secrete substances which are favourable to the growth of *E. histolytica.* He has succeeded in cultivating it, using the peritoneal exudation derived from guinea-pigs injected intraperitoneally with dysenteric mucus and pus.

Noc has recently described an Entamœba in the stools of dysenteric patients somewhat similar to *Entamœba histolytica*, but capable of cultivation in association with bacteria.

Entamœba tropicalis Lesage 1908.

Lesage, from his studies of tropical dysentery, has come to the conclusion that, just as there is an *Entamœba coli* Lösch parasitic, but non-pathogenic, in the intestine of man in warm and temperate countries, so there is another amœba parasitic, but non-pathogenic, in the intestine of man in the tropics. This parasite he names *E. tropicalis.*

It resembles *Entamœba coli* by having a nucleus which contains much chromatin and by becoming encysted, but it differs from the same in having a clearly visible ectoplasm, by the small size of its cysts, and by the fact that the nucleus of the cysts break up into number of nuclei, which are from three to several (he draws thirtee in one cyst). This entamœba can be cultivated along with bacteri but is non-pathogenic to animals.

Lesage considers this to be the same amœba which was studie and cultivated by Musgrave and Clegg, and thinks that the pro duction of dysenteric symptoms in their experiments was due t

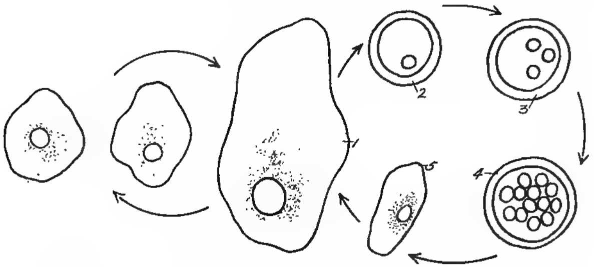

FIG. 45.—DIAGRAM OF THE LIFE-CYCLES OF ENTAMŒBA TROPICALIS LESAGE.

(Constructed from Lesage's drawings in the *Bulletin de la Société de Patholog Exotique*, showing binary fission and spore formation.)

contamination with the minute spores of *Entamœba histolytic* Walker in 1908 describes as a new species *E. hominis*, whic may perhaps be the same as *E. tropicalis*.

Pathogenicity.—It is a harmless commensal in the alimentar canal of man.

Culture.—It can be cultivated in symbiosis with bacteria.

Entamœba undulans Castellani 1905.

This amœba was found in fæces from persons suffering fro diarrhœa in Ceylon together with other intestinal protozoa—*e.g*

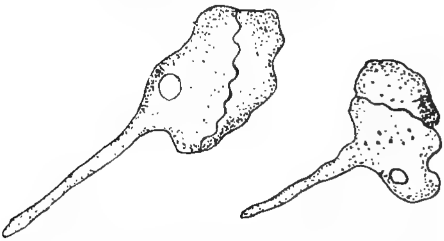

FIG. 46.—ENTAMŒBA UNDULANS CASTELLANI.

Cercomonata and Trichomonata. A somewhat similar amœba h been found by Gauducheau.

It varies in size, being from 12 to 30 μ in diameter, but there ma be much smaller individuals. It has no flagella, but possesses undulating membrane and long straight pseudopodia, which are rapidly emitted and retracted, only one pseudopodium being protruded at a time. There is no marked differentiation into ectoplasm and endoplasm, and a non-contractile vacuole is usually to be seen. The cytoplasm, which is finely granular, often contains bacteria. Castellani was inclined at one time to consider this parasite as a developmental stage of *Cercomonas hominis*.

Entamœba tetragena Viereck 1907.

Synonym.—*E. africana* Hartmann and v. Prowazek 1907.

Entamœba tetragena has been found in cases of dysentery in South Africa, and also in South-West Africa and South America.

It possesses a distinct ectoplasm, which is visible when a pseudopodium is extruded, and a granular endoplasm containing red cells, a large round nucleus, which is visible during life, and very large chromidial masses, which, according to Bensen, are characteristic. In asexual reproduction the nucleus first divides by mitosis into two, and then the cytoplasm follows suit. In sexual reproduction the cytoplasm becomes clearer, the nucleus divides into two nuclei, which, after reduction, undergo zygosis, which indicates that auto-

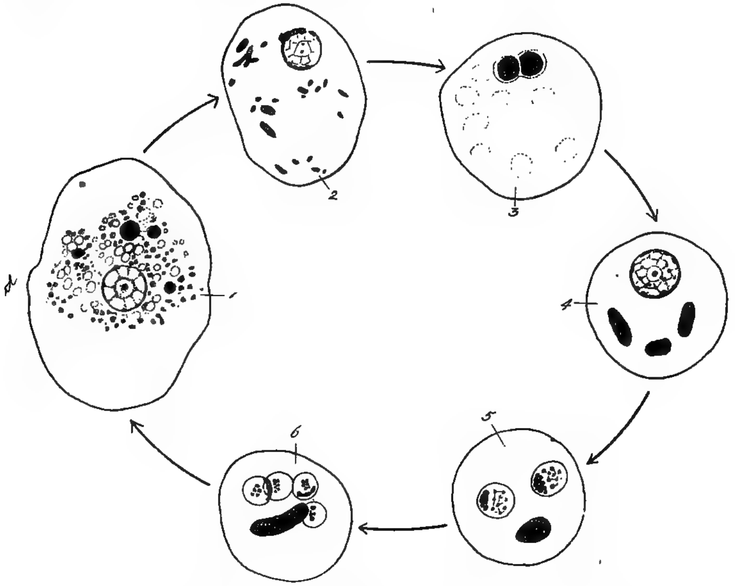

FIG. 47.—DIAGRAM OF THE LIFE-CYCLE OF ENTAMŒBA TETRAGENA VIERECK.

(Constructed from Hartmann's drawings in the *Archiv für Schiffs-und Tropen-Hygiene.*)

1, Fully-grown parasite; 2-6, stages in encystment and nuclear division.

gamy or self-fertilization takes place. The uninuclear zygote no encysts, and its nucleus divides, forming first two and finall four nuclei. The further history of the cyst is not known. Th *Entamœba* is probably a cause of amœbic dysentery in certai countries.

Entamœba phagocytoides Gauducheau 1908.

Entamœba phagocytoides was discovered by Gauducheau in Ind China in a case of dysentery. It is very small—only 2 to 15 μ i diameter—very activel motile, and possessin a well-developed ect plasm. It can be easil cultivated on ordinar agar-agar inoculate with *Bacillus typhosu* or other bacteria, whic it readily engulfs an digests. Some indivi uals show in the cytoplasm peculia spirochæte-like bodies.

Entamœba buccalis Prowazek 1904.

This amœba was de scribed as a new specie by Prowazek in 190 It was found in th mouths of person suffering from dent caries, and possesses distinct ectoplasm, fro which the pseudopodi are produced. Th nucleus is large, sub central in position, an poor in chromatin. Th food of the amœba composed of leucocyte bacteria, and detritu The development is by binary fission and a spore-formation some what like *Entamœba histolytica*.†

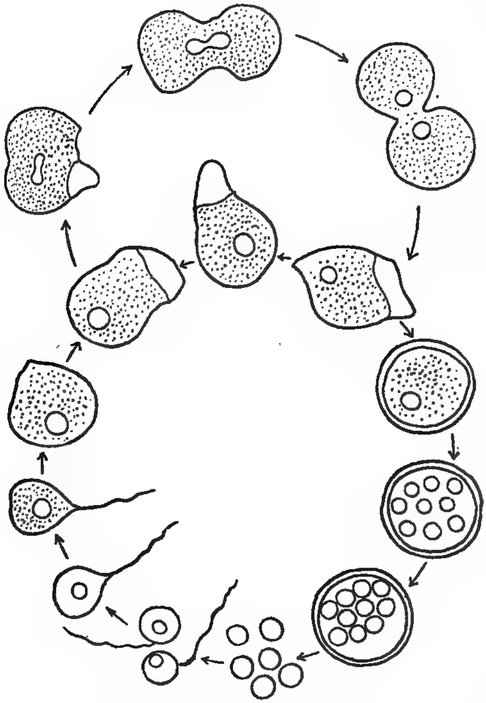

FIG. 48.—DIAGRAM OF THE LIFE-CYCLES OF PARAMŒBA HOMINIS CRAIG.

(After Craig, from the *American Journal of Medical Sciences*.)

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* **Entamœba minuta** Elmassian 1909.—This amœba, found by Elmassia in a case of chronic dysentery in South America, resembles *Entamœb tetragena*, but is much smaller, rarely exceeding 14 μ in diameter. There is n differentiation between the ecto- and endoplasm. The nucleus is invisib in fresh preparations, and, when stained, is rich in chromatin. Encyste forms contain four nuclei.

† **Entamœba nipponica** Koidzumi 1909.—This entamœba was found b Koidzumi in the motions of cases of dysentery and in healthy people in Japa

Genus 2. Paramœba Greeff.

Paramœba is usually described as one of the Sarcodina, but Hartog probably rightly considers that it belongs to the *Cryptomonadinæ* of the Mastigophora. The life-history of *Paramœba eilhardi* Schaudinn has been worked out by Schaudinn. It is a flat, discoidal protozoon, with short, lobose pseudopodia.

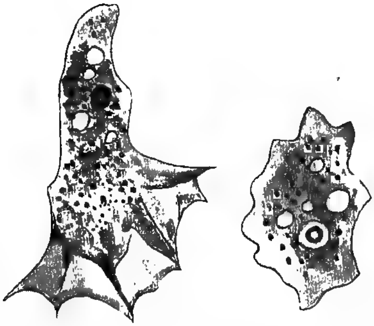

FIG. 49.—LEYDENIA GEMMIPARA SCHAUDINN.

(After Schaudinn.)

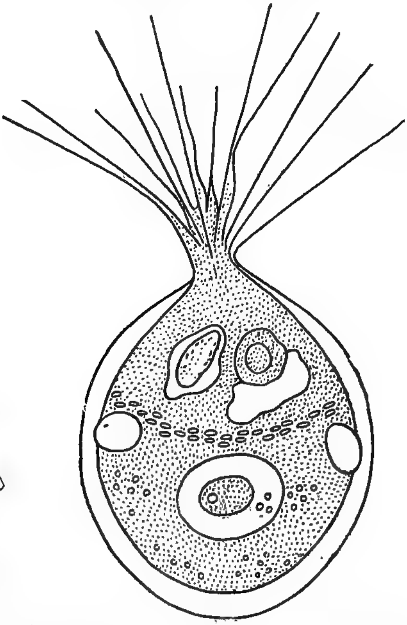

FIG. 50.—CHLAMYDOPHRYS ENCHELYS EHRENBERG.

(After Cienkowsky.)

Besides the nucleus, there is a cytoplastic body, called by Schaudinn the 'Nebenkörper.' Reproduction is by simple fission, or by the parasite becoming encysted, and then the 'Nebenkörper,' and later the nucleus, breaking up into a number of divisions, and finally the protoplasm segmenting around these to form spores, each containing a piece of the 'Nebenkörper' and a piece of the nucleus. These spores develop two flagella each, and, breaking out from the cyst, and increasing by longitudinal division, in due course lose their flagella and become young amœbæ.

Paramœba hominis Craig 1907.

Paramœba hominis is a rare parasite found in natives in the Philippine Islands. In its fully-grown amœboid stage it is from 15 to 25 μ in diameter,

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In the former case it is associated with *Entamœba histolytica*, which it resembles in size (15 to 30 μ) and in the marked difference between the ecto- and endoplasm. The pseudopodia are never spinose; the endoplasm is vacuolated, and more granular than in *E. histolytica*. The nucleus is well defined (5 to 7 μ), and rich in chromatin. This entamœba reproduces by fission schizogony and sporogony.

with well-defined ecto- and endoplasm when moving, but not so when at re The nucleus is distinct, and is composed almost entirely of chromatin.

This amœba can reproduce by binary fission for some time, at the end which it encysts and divides into a number of small spherical bodies, whi when liberated by the bursting of the cyst-wall, develop long, delicate flagel and move about actively. These flagellates grow rapidly, and, eventual becoming quiet, lose their flagella, and develop into amœbæ (Fig. 48).

Pathogenicity.—It is generally associated with a severe form of diarrhœ and is at times the only organism to be found to account for the sympton but it is not known whether it is truly the cause of the diarrhœa or not.

Genus 3. Leydenia Schaudinn 1896.

Leydenia gemmipara Schaudinn 1896.

Lieberkuhn observed cells in ascitic fluid taken from persons sufferi from malignant growths which moved about, but as to the nature of which did not make any determination. Leyden also observed cells of this nature two similar cases, and Schaudinn carefully described them.

They were spherical or irregularly polygonal, 3 to 36 μ in diameter, wi knobs projecting from the surface. They possessed a distinct ectoplasm a hyaline pseudopodia. There was a large vesicular nucleus. Developme took place by binary fission and gemmation (Fig. 49).

Schaudinn came to the conclusion that these bodies were protozoa belongi to the Rhizopoda, and called them *Leydenia gemmipara* Schaudinn. already remarked, Lauenstein and Behla have also recorded the discovery the organism in a case of cancer. According to Schaudinn, it is the amœbo stage of *Chlamydophrys enchelys*.

ORDER II. THECAMŒBIDA, FAMILY GROMIIDÆ.

Chlamydophrys enchelys Ehrenberg.

Synonym.—*Chlamydophrys stercorea* Cienkowsky 1876.

This rhizopod (Fig. 50) though not a parasite of man, is of importanc because it can be found growing in human fæces, as well as in those of the co the rabbit, the mouse, and the lizard. It is oval in form, enclosed by a shel except anteriorly, where the filiform pseudopodia project. The body of th parasite is divisible into an anterior portion, in which lie the contracti and food vacuoles, and a posterior with the nucleus. Reproduction is b 'bud-fission,' by which is meant that half the protoplasm protrudes at th mouth and forms a new shell, and then separates from the other half, whic retains the old shell. If two forms reproduce by 'bud-fission' close togethe the daughter cells may partially coalesce (plasmogamy), forming large coloni of twenty or more individuals. The parasite may become encysted.

The sexual process starts by the extrusion of all foreign substances and th collection of the remainder of the plasma and the chromidia into the shel The chromidial mass breaks up into a number of nuclei, never more tha eight, around which the plasma divides, forming swarm cells, which, developin two flagella at one pole and escaping from the cell, conjugate with the swar cells of another individual, and then become encysted. When the cy ruptures under favourable circumstances, a little amœba escapes, whic speedily forms a shell, and becomes in due course an adult Chlamydophrys.

PHYLUM II. MASTIGOPHORA DIESING 1866.

Definition.—The Mastigophora are protozoa with one or mor permanent organs in the form of flagella, which serve for locomotio and at times for the capture of food.

They are usually small in size, but have a great tendency t colony formation. The ectoplasm is present in the form of sheath called the periplast, a term which is really botanical in its meaning. This periplast may be drawn out into an undulating membrane which helps locomotion.

There is a difference of opinion as to which is the anterior end of the mastigote. We believe, with Sambon, that the non-flagellate end should correctly be considered as the anterior end, but several authorities hold quite different views, and our anterior end will correspond with many other writers' posterior. Very often there is a depression somewhere on the surface of the animal, generally near the base of the flagellum, which is intended for the reception of food, and is called the mouth or cytostome ; more rarely there is an œsophagus leading into the interior of the cell. Nutrition may be holozoic or holophytic, but this hardly concerns us, as the forms to be described are all parasitic, and live in fluids from which they absorb nourishment by their whole surface.

In the cytoplasm there is a nucleus, and in certain forms two nuclei : a trophonucleus for nutrition, and a kinetonucleus for movement. The character of these nuclei will be dealt with in detail in the Binucleata, section Trypanosomidæ. The cytoplasm may also contain food vacuoles, contractile vacuoles, chromatin particles, and metaplastic granules.

Reproduction takes place asexually (schizogony) by multiple or simple division or spore-formation, and also by true sexual reproduction (sporogony), brought about by conjugation with zygosis and the formation of a synkaryon. This gives renewed vigour to the animal, which now reproduces quickly asexually. Latent or encysted forms are also known. In the Binucleata the life-history is very complex, taking place in two hosts—a vertebrate and an invertebrate.

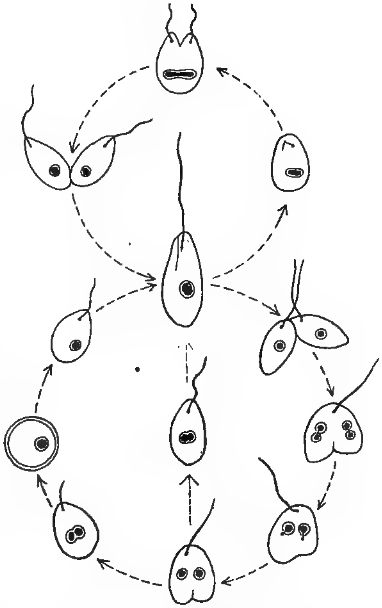

FIG. 51. — DIAGRAM OF THE LIFE-CYCLES OF A MASTIGOTE (COPROMONAS SUBTILIS DOBELL).

(After Dobell, from the *Quarterly Journal of Microscopical Science.*)

The whole subject of the structure and life-history of the parasitic Mastigophora requires much further research, which, indeed, is being rapidly carried out all over the world—in fact, so rapidly that it is hardly possible to write anything on the subject as a whole which will not be quickly out of date.

The classification is most difficult, and, indeed, the state o knowledge is not such as to permit of a proper arrangement. Th scheme proposed below must be looked upon as merely provisiona and is mainly dependent upon the work of Sambon and Hartman

Classification. — The Mastigophora are divided into six sub classes by Willey and Hickson.

Subclass I. Lissoflagellata }
Subclass II. Choanoflagellata } Euflagellata.
Subclass III. Phytoflagellata }
Subclass IV. Dinoflagellata } Not parasitic.
Subclass V. Cystoflagellata }
Subclass VI. Silicoflagellata.—Parasitic on radiolarians.

CLASS. EUFLAGELLATA.

Mastigophora with one to several flagella. They have a tendenc to form colonies. The euflagellata are divided into two subclasses

Subclass I. Lissoflagellata.—Flagellum, single or multipl without collar.

Subclass 1. Choanoflagellata. — Flagellum always singl and with a collar. Non-parasitic.

Subclass. Lissoflagellata Lankester.

The subclass Lissoflagellata is divided into three orders :

Order 1. *Monadidea.*—Minute forms with one or more flagella
Order 2. *Euglenoidea.*—Non-parasitic.
Order 3. *Chromomonadidea.*—Non-parasitic.

Order. Monadidea Bütschli.

The Monadidea comprise four tribes :

Tribe 1. *Pantastomina.*—Non-parasitic.
Tribe 2. *Protomastigina.*
Tribe 3. *Polymastigina.*
Tribe 4. *Binucleata.*

Tribe 2. Protomastigina.

Definition.—Monadidea, in which the food is taken in at som definite point near the base of the flagellum, with one or more simpl contractile vacuoles, without colour, and usually with reserves of fa holozoic, saprophytic, or parasitic. The Protomastigina may b classified into :

Subtribe 1.—Monomastigoda with one flagellum. Genera : *Cer comonas*, *Monas.*

Subtribe 2.—Paramastigoda, with one long and one or tw short flagella. Genus : *Bodo.*

Subtribe. Monomastigoda.

Cercomonas Dujardin and Bütschli.

Cercomonas is a protomastigote, oval or rounded, with on flagellum.

Cercomonas hominis Davaine 1854.

Davaine found these flagellata in the evacuations of cholera patients, and since then they have been found in numerous cases of diarrhœa, and even in normal stools, in which we have often seen them. They have also been found in sputum in cases of gangrene of the lungs and in pleural exudations. They have been reported as parasites of dogs, ducks, and fowls. There has, however, been the utmost confusion as to what is meant by Cercomonas, and many writers have confused it with Trichomonas.

A Cercomonas is a round or pear-shaped parasite averaging from 8 to 10 μ in diameter, with a long flagellum projecting from the more pointed end. There is no undulating membrane. The nucleus is small, indistinct, and usually situated near the flagellar extremity, where a mouth has also been described. Reproduction is by binary fission, and Perroncito and Piccardi have described encystment.

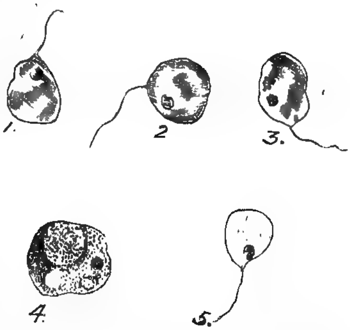

FIG. 52.—CERCOMONAS HOMINIS DAVAINE.

1-3, and 5, flagellate forms; 4, encysted form.

According to our experience at autopsies, the parasite may live not only in the small intestine, as generally stated, but also in some cases in the large intestine.

Cercomonas is readily killed, as observed by Castellani and Willey, by a solution of methylene blue (1 in 3,000).

Cercomonas vaginalis Castellani and Chalmers 1909.

This is a pear-shaped or rounded parasite, measuring 5 to 10 μ in its maximum diameter, and provided with one flagellum, a small nucleus, and food vacuoles, but without a pulsating vacuole. It is not uncommon in the vagina of native women in Ceylon.

Other Species.—*C. anatis* Davaine, in the alimentary canal of ducks; *C. canis* Gruby and Delafond, in the same of dogs; *C. gallinarum* Davaine, in fowls; *C. perryi* Castellani 1907, found in monkeys (*Macacus pileatus* and *Semnopithecus priamus*), is practically identical with *C. hominis* as regards morphological characters.

SUBTRIBE. PARAMASTIGODA.

Bodo Stein.

The genus *Bodo* Stein comprises oval, or elongated (30 μ), naked, colourless protomastigotes, which possess two flagella situated anteriorly, and which are generally of different sizes. The smaller points forward, while the larger trails behind. The difference in size, however, may not be marked.

A mouth is always present, but an œsophagus seldom. The nucleus lies in the middle. Reproduction is by longitudinal binary fission or swarm-spore formation after conjugation.

The genus *Bodo* comprises several species parasitic in animals—*e.g.*, *B. helicis* Leidy in the generative canals of species of Helix ; *B. iuli* Leidy, in the alimentary canal of *Julus marginatus* ; *B. lacertæ* Grassi 1881, in the cloaca of *Lacerta viridis* and *muraria* ; *B. gryllotalpæ* Grassi 1879, in the larva of gryllotalpa. In man [illegible] ~~one form~~ has been described.

Bodo urinarius Hassall 1859.

Synonyms.—*Cystomonas urinarius* Blanchard 1886, *Plagiomonas urinaria* Künstler 1895.

Hassall in 1859 saw a flagellate organism in decomposing urine, and called it *Bodo urinarius*. Künstler, in 1883, again reported the occurrence, but this time in urine which was supposed to be freshly passed. It is an elongated flagellate, with a long, tapering, anterior extremity, and a broader posterior extremity with a depression, from which two flagella project, and near which the nucleus lies in the cytoplasm. It measures 10 μ in length by 4-5 μ in breadth.

Monas Stein.

Monas pyophila R. Blanchard 1895.

This parasite is described by Grimm as being present in the pus from a pulmonary and a hepatic abscess in a Japanese woman. It is shaped like a large spermatozoon, and consists of a heart-shaped body, surrounded by a thick cuticle, which is divided into three parts. The rounded end of the heart carries a long, retractable projection covered by cuticle, except at its tip, where a flagellum projects.

TRIBE 3. POLYMASTIGINA Blochmann.

Monadidea, possessing more than two similar or dissimilar flagella, and a special mouth aperture for food.

The parasitic members of this suborder are classed by Doflein into :

Family 1. Tetramitidæ Bütschli. Family 2. Polymastigidæ Bütschli.

FAMILY 1. TETRAMITIDÆ Bütschli.

Polymastigina with three or four flagella arising together. Genus : *Trichomonas*. Recently we have come across two new flagellates in the stools of some cases of agchylostomiasis :

Bodo asiaticus Castellani and Chalmers 1910.

This flagellate is pear-shaped, about 8 to 15 μ in length, with two flagella originating from the same pole, without undulating membrane, and with a nucleus fairly rich in chromatin. It is capable of amœboid movements, though no true pseudopodia are emitted. It is easily cultivated on artificial media in symbiosis with bacteria. This flagellate we classify provisionally under the genus Bodo.

Heteromita zeylanica Castellani and Chalmers 1910.

This flagellate is elongated, 8 to 15 μ in length by 3 to 4 μ in breadth, with single flagellum at each pole, and a nucleus fairly rich in chromatin. No undulating membrane or pulsating vacuole, but with chromidia in the cytoplasm. It is not cultivable. This flagellate we classify provisionally under the genus Heteromita.

Trichomonas Donné 1837.

Tetramitidæ with pyriform bodies, the non-flagellate end being pointed, and the flagellate rounded and carrying three to four flagella, which may be fused together. There is an undulating membrane which runs from the non-flagellate extremity backwards to the flagellate end. The nucleus lies near the flagellated end. Parasitic in vertebrates and invertebrates, chiefly in the intestine.

Species.—*T. vaginalis* Donné 1837, *T. hominis* Davaine 1854, *T. pulmonalis* Schmidt 1895.

Trichomonas vaginalis Donné 1837.

Synonym.—*T. irregularis* Salisbury 1868.

This parasite lives in the vagina when the reaction of the mucus is acid. It is found in Europe, and we have observed it in Ceylon and in equatorial Africa. It has also been reported to occur in the urethra in men, after cohabitation with women infected with the parasite.

It is not transferable to rabbits, guinea-pigs, or dogs. It has not been cultivated, nor is it understood how women become infected.

T. vaginalis is fusiform or pear-shaped in appearance, length from 15 to 25 μ, and breadth from 7 to 12 μ. The non-flagellate extremity is pointed and the flagellate extremity rounded. The parasite is generally considered to be harmless, but we have, however, found it much more frequently in women suffering from vaginitis than in normal women.

Trichomonas hominis Davaine 1854.

Synonyms.—*Cercomonas hominis* Davaine 1854, *C. intestinalis* Lambl 1875, *T. intestinalis* Leuckart 1879, *Monocercomonas hominis* Grassi 1882; *Cimænomonas hominis* Grassi 1883.

The utmost confusion has existed between this species and *C. hominis* and *T. vaginalis*. It has been found in cases of diarrhœa in Europe, India, and Ceylon, but in small numbers may be found also in the intestine of individuals apparently healthy; it has also been reported from the mouth cavity. It seems to prefer to live in alkaline mucus.

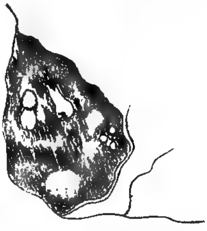

FIG. 53.—TRICHOMONAS HOMINIS DAVAINE.

T. hominis is pear-shaped, with a breadth of from 18 to 25 μ, with three flagella at its broadest end, and an undulating membrane. The cytoplasm contains a rather indistinct nucleus, and one or several non-pulsating vacuoles.

It has not been transmitted to animals, nor has it been cultivated. It can reproduce by longitudinal division, but forms are to be seen indicating encystment and conjugation.

Trichomonas pulmonalis Schmidt 1895.

This form has been found by Schmidt and St. Artault, Leyden and Jaffé, in the sputum and lungs of persons suffering from phthisis, gangrene, and putrid bronchitis.

Other Species.—*T. batrachorum* Perty 1852, in the cloaca of *Rana temporaria*, *R. esculenta*, *Bufo vulgaris*, and *Hyla arborea*, in Germany and Italy; *T. suis* Gruby and Delafond, in the alimentary canal of pigs; *T. limacis* Dujardin, in the gut of *Limax agrestis; T. lacertæ* Blochmann, in the cloaca of *Lacerta agilis, T. caviæ* Davaine, in the large bowel of guinea-pigs; but this last may perhaps be separated off into a separate genus *Trichomastix*, with one long flagellum directed across the body. *T. perronciti* Castellani 1907, in monkeys suffering from diarrhœa, is very similar morphologically to *T. hominis*. *T. columbarum* Prowazek and Aragao 1909, is found in the buccal mucosa of pigeons.

FAMILY 2. POLYMASTIGIDÆ Bütschli.

Polymastigina, with four to six flagella at the broader and two at the narrower end.

Genera.—1. *Polymastix* Bütschli, with two or three membranes.

2. *Hexamitus* Dujardin, with two flagella on each side of the rounded end.

3. *Lamblia* Blanchard 1888.

Polymastix melolonthæ Grassi is found in the alimentary canal of the larva of *Melolontha vulgaris*, and species of *Hexamitus* are *Hexamitus muris* Grassi, in the intestine of species of *Mus*, and also that of *Arvicola arvalis; H. intestinalis* Grassi is found in *Rana esculenta* and *Bufo vulgaris;* and *H. vulgaris* Dujardin in the alimentary canal of *Ostrea edulis* and *angulata*, according to Certés.

Lamblia R. Blanchard 1888.

Polymastigidæ, with pear-shaped body, the broad end having a hollow, from the borders of which three pairs of flagella take origin. The pointed end carries the fourth pair of flagella.

Lamblia intestinalis Lambl 1859.

Synonyms. — *Cercomonas intestinalis* Lambl 1854, *Hexamitus duodenalis* Davaine 1875, *Dimorphus muris* Grassi 1879, *Megastoma entericum* Grassi 1881, *Megastoma intestinale* Blanchard 1886, *Lamblia intestinalis* Blanchard 1888.

This parasite lives in the intestine of different species of the genus *Mus* (*M. musculus, M. rattus, M. norvegicus, M. silvestris*); also in species of Arvicola (*A. arvensis* and *A. amphibius*); also in the rabbit, the cat, the dog, the sheep, and man.

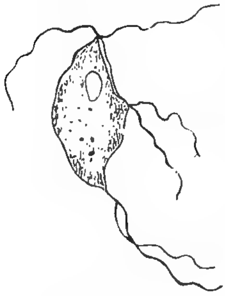
FIG. 54.—LAMBLIA INTESTINALIS LAMBL.

It was first observed by Lambl in the mucous intestinal evacuations of children in Russia, then by Grassi in Italy, in Germany by Moritz, in Austria by Jaksch, in Egypt by Kruse, and we have observed it several times in Ceylon.

It occurs in the large bowel of man, and it and its cysts can be found in the fæces. The infection of man is brought about by swallowing the encysted forms. This has been proved experimentally by Grassi, and as it occurs in mice, it is quite easy to see how infection of foodstuffs is possible.

L. intestinalis is an actively motile organism about 12 to 21 μ in length, and about 5 to 12 μ in breadth. It is pear-shaped, being surrounded by a thin periplast (ectoplasm) which keeps its form. The under surface (when attached) is excavated with a well-defined border, which is interrupted at the site of the cytostome. This hollow is probably a kind of peristome, and is useful in fixing the parasite to the intestinal epithelium. The cytoplasm contains a dumb-bell-shaped refractile nucleus, which is said to be connected with the flagella.

The parasite can become encysted into oval cysts 10 μ in length by 7 μ in breadth, surrounded by a hyaline cyst-wall.

Recently Noc has investigated *Lamblia intestinalis*, and has concluded that the recognition of different species is not justifiable He draws attention to the presence of three nuclei, and finds that reproduction takes place by longitudinal division and by encystment with multiple nuclear division and the formation of numerous small forms, which escape after the cyst-wall has disappeared, and then grow into the fully developed parasite. He considers that rats and mice are to be regarded with suspicion with regard to the spread of the parasite which, escaping with their fæces, may infect food and water.

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Dobell (1909). Quarterly Journal of Microscopical Science, lii. 255. (Considers the name should be *C. stercoralis*.)
Schaudinn (1902). Arb. aus d. Kaiserl. Gesundh., xix. Bd. 3, p. 560.

Mastigophora.

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CHAPTER XII

BIOLOGICAL CAUSES OF DISEASE (*continued*)—PROTOZOA

Binucleata—Hæmoproteidæ—Leucocytozoidæ—Trypanosomidæ — Herpetomonidæ—Plasmodidæ—Spirochætacea—References.

TRIBE 4. BINUCLEATA HARTMANN 1907.

Synonyms.—*Hæmoprotozoa* Sambon 1906; *Hæmocytozoa* Danilewsky 1885, *pro parte; Hæmosporidia* Mingazzini 1890, *pro parte; Hæmoflagellata* Woodcock, *pro parte.*

Definition. — Parasitic Mastigophora, generally inhabiting the blood plasma or blood cells of vertebrates, but may be found in other organs and tissues during a 'vegetative cycle,' characterized by non-sexual multiplication (schizogony); and in the body of blood-sucking invertebrates during a 'sexual cycle,' characterized by sexual multiplication after conjugation of similar or dissimilar gametes (sporogony).

The separation of the Hæmosporidia from the Telosporidia, and the grouping of them with the Hæmoflagellata and their allies into one order, appears to us to be most excellent, and we therefore follow Hartmann and Sambon in this matter. Further, Sambon has subdivided the forms so grouped together, according to differences in the oökinete and sporogony, which also we propose to follow, as it appears to us to arrange them in some attempt at a natural classification. We are fully aware that all classifications are artificial, and dependent entirely upon the state of knowledge at the moment, but in endeavours to systematize knowledge, some scheme must be adopted, even if it is only temporary.

It is Schaudinn's work which has brought about this classification of the Hæmoflagellata with the Hæmosporidia. Much has been written against Schaudinn's views, and there remains the fact that no one else has traced out fully the life-history of a trypanosome: and although certain observations appear to go against Schaudinn, many others corroborate, strengthen, and extend his views.

Thus, Woodcock shows that a halteridium parasite in the chaffinch (*Fringilla cœlebs*) becomes in certain phases a little trypanosome.

This is the first conclusive evidence in support of Schaudinn, and in the face of this confirmation it would be rash to doubt the rest of that distinguished scientist's work.

Hartmann and Raven's researches on Proteosoma support the union of the two families, for they find—

1. *In the Merozoites*, rare flagellate forms, pear-shaped in appearance, with a small granule, which they interpret as a kinetonucleus at one extremity.
2. *In the Macrogametocytes and Microgametocytes*, some chromatic spheres, which they interpret as non-functional kinetonuclei, and say that sometimes a filament unites this sphere to the karyosome of the principal nucleus.
3. *In the Microgametes*, the structure of a trypanosome, with a kinetonucleus at one extremity, and a chromatic filament bordering an undulating membrane, which, however, is only recognizable in the fresh condition.

Sambon divides the tribe Binucleata into two subtribes—Acystina and Encystina, according to whether the oökinete does or does not encyst.

The classification is as follows:

SUBTRIBE I. ACYSTINA.

Binucleata in which the oökinete remains free and does not become encysted:

Family 1. Hæmoproteidæ.
Family 2. Leucocytozoidæ.

SUBTRIBE 2. ENCYSTINA.

Binucleata in which the oökinete becomes encysted:

Family 3. Trypanosomidæ.
Family 4. Herpetomonidæ.
Family 5. Plasmodidæ.

With regard to the Trypanosomidæ and Herpetomonidæ, it is obvious that if Minchin is correct with regard to the encystment of *Trypanosoma grayi*, and Prowazek with regard to that of *Herpetomonas muscæ-domesticæ*, these families belong to the Encystina, and not to the Acystina. The Plasmodidæ are clearly Encystina.

The Spirochætes are undoubtedly closely allied to the Binucleata, especially to the Leucocytozoidæ, and hence, perhaps, should be provisonally placed as an appendix to this tribe.

FAMILY 1. HÆMOPROTEIDÆ SAMBON 1906.

Acystina, in which the schizonts and gametocytes are alternately free and active or endocellular and resting, the former having a trypaniform and the latter a halteridial appearance. The oökinetes which are free give rise to indifferent and sexual forms, of which the former repeatedly divides, and gives rise eventually to sporozoites.

This family contains one genus and several species.

Genus.—*Hæmoproteus* Kruse 1890.

Synonyms.—*Halteridium* Labbé 1894, *Laverania* Laveran 1899, *Trypanosoma* Schaudinn 1904, *Trypanomorpha* Léger 1906.

Historical.—These parasites were first described by Grassi and Feletti in the blood of birds in 1890 as *Laverania*, a term altered by Labbé in 1894 to *Halteridium danilewskyi*. In 1904 came Schaudinn's paper showing that they were stages in the life-history of trypanosomes, which has been supported by the work of the Sergents, and has been severely criticized by Novy, McNeal, Ross and Thiroux, who believe that Schaudinn made a mistake, and that the flagellates and intracorpuscular parasites are quite distinct. In 1908 a paper by Aragao appeared on *H. columbæ*, which certainly does not support Schaudinn's views; but in 1909 Woodcock's researches, as already mentioned, strongly support that distinguished protozoologist.

Hæmoproteus noctuæ Celli and Sanfelice 1901.

H. noctuæ goes through the cycle of schizogony in *Glaucidium noctuæ* Retz, the little owl, and its sporogony in *Culex pipiens* Linnæus..

When this gnat sucks the blood of a little owl infected with hæmoproteus, two halteridial forms in the owl's corpuscles are seen to undergo development in its stomach. These two forms are the microgametocytes and the macrogametocytes.

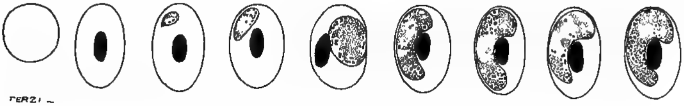

FIG. 55.—HÆMOPROTEUS MANSONI SAMBON, SHOWING THE DEVELOPMENT OF THE GAMETOCYTES.

(After Sambon.)

Microgametocyte.—The microgametocyte appears as a typical halteridium parasite enclosed in an erythrocyte, and possessing pale clear cytoplasm, with coarse hæmozoin granules and a large single nucleus, which is composed of eight groups, each containing trophic and kinetic elements.

Macrogametocyte.—The macrogametocyte is a typical halteridium, laden with food granules, lying in a pale, disorganized erythrocyte. It has a rather small trophonucleus, alongside of which is a small kinetonucleus.

In the Mosquito.—When these gametocytes reach the alimentary canal of *Culex pipiens*, they escape from the erythrocytes, and appear free in the lumen of that canal, and proceed first to reduction and then to zygosis, with the formation of a zygote.

The whole process has been carefully worked out by Macallum in another species of halteridium, and is confirmed by Schaudinn in the present species.

Formation of the Microgametocyte.—The microgametocyte is a clear hyaline body, which, on escaping from the red blood-corpuscles, throws out active flagella, which, after beating about a little, break loose, forming the free microgametes. Schaudinn studied the cytological processes underlying these grosser changes, and found that the trophonuclei were reduced to four chromosomes, while the eight kinetonuclei remain, and, separating from the parent nucleus, form microgametes in the way presently to be described for the development of a male oökinete into a male trypanosome.

The Microgamete.—The microgamete is very thin, and tapering at the posterior extremity, where it ends in a tail-like prolongation of the cytoplasm, containing a portion of the trophonucleus. The anterior end is acutely conical.

The trophonucleus is elongated into a long thread, extending from th anterior to the posterior end of the body, and carrying four chromosomes i the form of dots at regular intervals.

The kinetonucleus is situate in the posterio third of the cytoplasm, and consists of a rathe elongated mass, with eight chromosomes and on intranuclear centrosome.

In addition to this centrosome there are tw others : an anterior, situate just at the base of th anterior conical projection, and a posterior, situat just anterior to the tail, being connected with th trophonucleus by a chromatin bar. The undulatin membrane runs from the anterior to the posterio centrosome, and is strengthened by eight myonemes.

Formation of the Macrogamete.—The macrogametocyte becomes rounded, and ruptures th remains of the erythrocyte, and is set free. Th centrosome of the trophonucleus disappears, an the chromatin forms a spiral thread, which separates by longitudinal and transverse divisions int four tetrads. The kinetonucleus first forms spindle, and then divides, causing the first reduction, which results in four dyads, and then a secon division follows, leaving four monads or singl chromosomes. The kinetonucleus now returns t its old position outside and close to the trophonucleus, and the macrogamete is fully developed.

Schaudinn was not able to trace out the reduction of the kinetonucleus, but it ultimately consist of four chromosomes and a centrosome, whic Woodcock points out, are not wholly sexual.

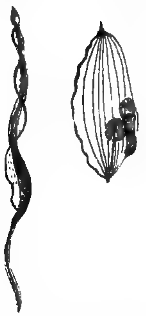

FIG. 56.—HÆMOPROTEUS NOCTUÆ CELLI AND SANFELICE.

(After Schaudinn.)

On the left is the microgamete, and on the right a scheme showing the arrangement of the nuclei, centrosomes, undulating membrane, and myonemes.

Zygosis.—This consists in the penetration of a microgamete into a receptiv cone, which has arisen from the cytoplasm of the macrogamete on the sid where the nuclei are situated.

The only parts which enter are the male trophonucleus, which is reduce and the male kinetonucleus, which is not reduced, but which now undergoe two divisions. The trophonuclei of the male and female elements fuse, an form the fusion spindle, at either end of which the kinetonuclei take u positions, and thus the zygote is formed.

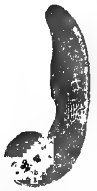

FIG. 57.—HÆMOPROTEUS NOCTUÆ CELLI AND SANFELICE : THE OÖKINETE.

(After Schaudinn.)

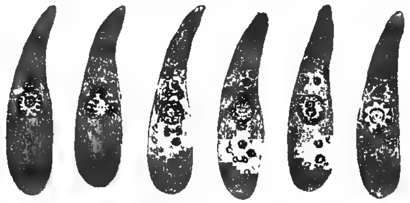

FIG. 58.—HÆMOPROTEUS NOCTUÆ CELLI AND SANFELICE : MATURATION OF THE OÖKINETE.

(After Schaudinn.)

Oökinete.—While zygosis is proceeding, and even before the comple formation of the synkaryon, the zygote becomes vermiform and motile, ar is therefore called an oökinete. It consists of an anterior, hyaline, chang able end, which is followed by a region of cytoplasm with vacuoles, then by denser region with the nuclear spindle just described, and finally a rounded posterior end, full of granules and hæmozoin. From this posterior end a portion of cytoplasm enclosing granules and hæmozoin, etc., is cut off, thus freeing the oökinete of waste material. The spindle of the synkaryon now consolidates to form eight chromosomes, which will constitute the trophonucleus, while the two kinetonuclei at either end of the spindle, meeting together, form a single kinetonucleus, which takes up a central position inside the trophonucleus, and divides into eight chromosomes, with a centrosome in its centre. The nucleus of the oökinete, therefore, consists of a central centrosome, with eight surrounding chromosomes, around which lie another eight chromosomes bordering the periphery.

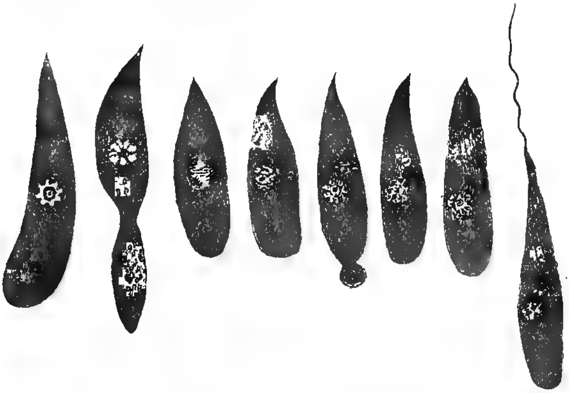

FIG. 59.—HÆMOPROTEUS NOCTUÆ CELLI AND SANFELICE.
(After Schaudinn.)

Formation of the indifferent oökinete and its development into the indifferent trypanosome.

But oökinetes are not all alike. On the contrary, Schaudinn describes three kinds :

1. *Indifferent Oökinete.*—Cytoplasm clear, and staining faintly, with one or two large vacuoles anteriorly, and having some granular material and hæmozoin still left.

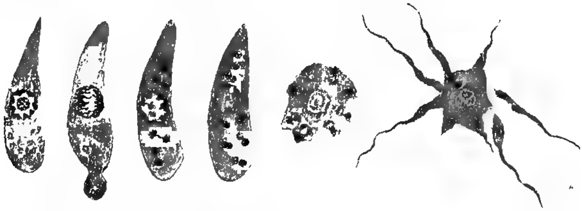

FIG. 60.—HÆMOPROTEUS NOCTUÆ CELLI AND SANFELICE.
(After Schaudinn.)

Formation of the male oökinete, and its development into the male trypanosome.

2. *Male Oökinete.*—Smaller than the indifferent or female forms, with cytoplasm almost hyaline, and much clearer than that of the indifferent form,

with granular material completely lacking, nucleus large, and rich in chro matin.

3. *Female Oökinete.*—Cytoplasm fairly dense, with plenty of granules, wit a nucleus smaller than in the indifferent form.

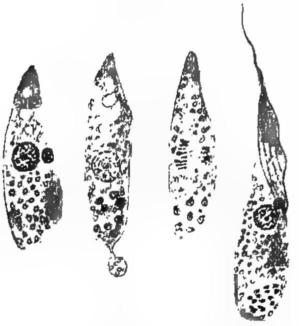

FIG. 61.—HÆMOPROTEUS NOCTUÆ CELLI AND SANFELICE: DEVELOPMENT OF THE FEMALE OÖKINETE AND THE FEMALE TRYPANOSOME.

(After Schaudinn.)

The Indifferent Ookinete.—The indifferen oökinete starts its development by expellin for a second time a quantity of hæmozoin while its kinetonucleus unites with the tropho nucleus, so that the nucleus now possesse eight compound chromosomes.

The centrosome becomes dumb-bell-shaped and forms an axial spindle, around which th chromosomes are arranged. These now divide and form a diaster by the different portion passing to either end of the spindle, which i heteropolar, the smaller half being kinetic i function. The nucleus now divides into larger portion, the trophonucleus, and smaller, the kinetonucleus. The former enter on a resting stage, while the latter proceed to the periphery, and forming another axia spindle at right angles to the length of th parasite, divides into two portions by it centrosome forming the axial spindle and th chromosomes the two ends of a diaster. On of these daughter kinetonuclei lying in th ectoplasm is attached to the other, lying i the endoplasm, by means of the axial spindle The ectoplasmic kinetonucleus forms another spindle, with a longitudinal axis which grows backwards along a fold of the ectoplasm, expanding it as it goes to the hinder end of the body. In this way an undulating membrane i formed, which, therefore, contains eight chromosomes—the myonemes—o each side of the folded ectoplasm, while the axial spindle, becoming excentric forms the flagellum. At the posterior end of the undulating membran the flagellum joins with the chromosomes, and grows out of the body t form the free flagellum, along which the ectoplasm is drawn for a shor distance.

Of the two centrosomes of this spindle, the distal one disappears, while th proximal one forms the blepharoplast at the root of the flagellum.

The endoplasmic daughter kinetonucleus becomes the kinetonucleus o the trypanosome, and thus is formed the indifferent trypanosome, which no multiplies by binary division. After some time it takes on a gregariniforr phase, and becomes att~~racted~~ached to an epithelial cell in the stomach of th mosquito by its flagellum, which is reduced to a short rod. While so attache it may multiply by binary division, and may also penetrate in between th cells of the stomach and encyst, losing its flagellum.

After a period of rest the trypanosome can become active again, but afte a time it must either (1) pass into the blood of the little owl; (2) become male or female form; (3) die out.

The Male Oökinete.—The male oökinete forms a heteropolar diaster, bu with a subdivision of the elements into male and female instead of into kineti and trophic.

The larger or female portion disappears, while the smaller or male portio forms eight double nuclei, with kinetic and trophic elements, which are di tributed throughout the cytoplasm.

The oökinete now becomes rounded, while the eight double nuclei trav to the periphery, which grows out into little elevations, each with a doub nucleus. Each little elevation grows into a little male trypanosome in th same manner as in the indifferent form, and breaks off from the 'rest body (*nucleus de reliquat*) of the parent cell. These male trypanosomes, accordin to Schaudinn, simply die off.

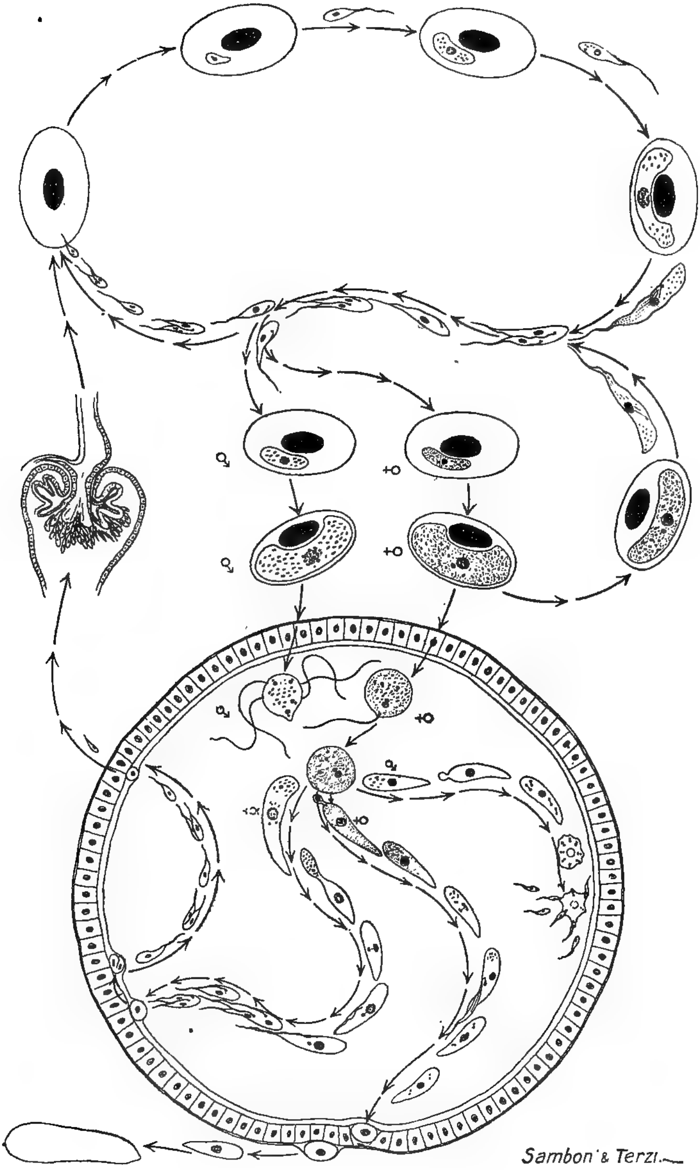

FIG. 62.—DIAGRAM SHOWING THE LIFE-CYCLE OF HÆMOPROTEUS NOCTUÆ CELLI AND SANFELICE.

(After Sambon and Terzi.)

The Female Oökinete.—In this form the same changes take place as in th male oökinete, but it is the small male nucleus which degenerates, after divid ing into a number of forms, while the large female nucleus, which consist of the trophic and kinetic elements, remains, and forms a trypanosome in th same manner as in the indifferent form.

The female trypanosome is slow moving, and does not divide, but ca become gregariniform, and lie quiescent between the epithelial cells for time. It can also pass into the ovaries and eggs, and lie dormant during th winter.

The female oökinete, however, undergoes parthenogenesis by losing it flagellar apparatus and developing a trophonucleus with a kinetonucleus i contact with it. The kinetonucleus now divides, and undergoes reduction while the trophonucleus also divides, one portion being lost. The reduce kinetonucleus, which has divided into two, now enters the trophonucleu from opposite sides, and fusing, forms the synkaryon of an oökinete, whic may become an indifferent, a male, or a female trypanosome.

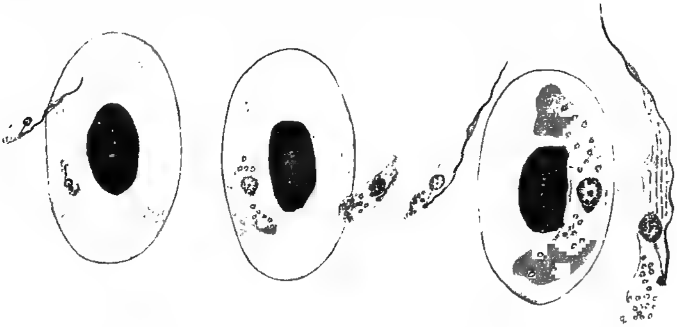

FIG. 63.—HÆMOPROTEUS NOCTUÆ CELLI AND SANFELICE.

(After Schaudinn.)

On the left a small trypanosome is seen entering a red corpuscle in the bloo of the little owl, and in the corpuscle is seen the first endocellular stage. Th second corpuscle shows a more advanced endocellular stage and the act o liberation into the liquor sanguinis. Farther to the right is seen a medium sized trypanosome. The third corpuscle shows the fully-grown halteridia form, while on the extreme right a fully-grown trypanosome is depicted.

In the Owl.—The male, female, and indifferent trypanosomes may b injected into the owl during the process of biting by the mosquito, but th majority are of the indifferent type. The male trypanosomes, if they ente die off. The indifferent trypanosomes divide in the blood until a small siz is reached, when they enter the erythrocytes, and become a young halter idium by the flagellar apparatus disappearing and the kinetonucleus approach ing the trophonucleus.

In twenty-four hours this parasite, which now contains hæmozoin, become active, and, re-forming its flagellar apparatus, leaves the blood cell usually a night as a typical *Trypanosoma noctuæ*. After a short period of activity i enters another erythrocyte, and grows till the next night, when it agai becomes free. This process takes place six times before the trypanosom attains its full size, when it undergoes repeated division until again smal thus completing the cycle of schizogony. The small extracellular forms ma be looked upon as the merozoites, and the intracellular forms as trophozoite and the large extracellular form as schizont. The sexual forms are develope from the merozoites—*i.e.*, the very young indifferent trypanosomes—whic enter the red cells, and become microgametocytes and macrogametocytes, thus completing the cycle of sporogony.

Remarks.—If this account be correct, it would point to an intimate relationship between the Plasmodidæ and the Trypanosomidæ, the former probably being evolved from the latter.

This description of Schaudinn's has been partially confirmed by several workers tracing out in part the life-histories of several trypanosomes. On the other hand, it is still unconfirmed *in toto*, and especially in the important point of the change of the trypanosome into the halteridium, and *vice versa*.

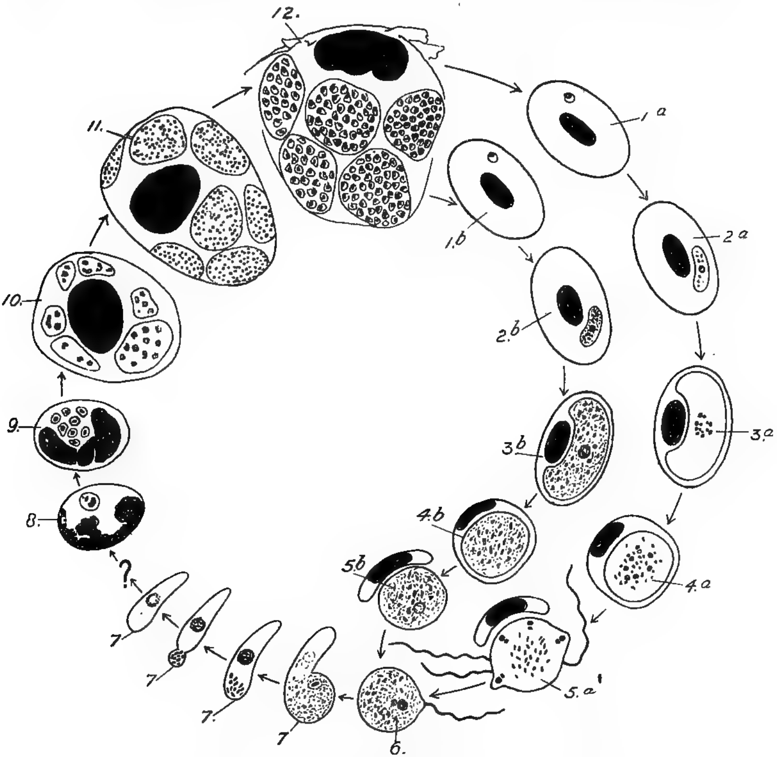

FIG. 64.—THE LIFE-CYCLE OF HÆMOPROTEUS COLUMBÆ CELLI AND SANFELICE.

(According to the researches of Aragao. After Aragao, from *Archiv f. Protistenkunde*.)

Novy and many others are convinced that Schaudinn is entirely wrong, and that he was dealing with a double infection of a halteridium and a trypanosome, both of which probably develop in entirely different ways.

Recently, as already stated, Woodcock has strongly supported Schaudinn's account, which very probably will be found to be correct.

Hæmoproteus columbæ Celli and Sanfelice 1891.

Hæmoproteus columbæ is the halteridium of *Columba livia* L. Its life-history is not exactly known at present, but has been studied by Ed. and Et.

Sergent and by Aragao. According to the latter observer, it would seem t have the usual two life-cycles of schizogony and sporogony joined into one taking place in *Columba livia* and in *Lynchia maura* or *L. brunea* (*lividicolor*) Oliv

Starting with the macro- and microgametocytes, which are of the sam appearance as in *H. noctuæ*, and which enter the gut of the *Lynchia* alon with the blood sucked from the pigeon, the usual processes of reduction with the formation of microgametes and macrogametes and oökinetes, an the clearance of waste matter from these latter, are gone through. The furthe changes undergone by the oökinete are at present unknown.

After the *Lynchia* bites a pigeon, a small binuclear parasite is to be found i a leucocyte, first at the site of the bite and later in the lungs, where th further development takes place. First the small parasite divides into number of mononuclear forms, which, along with the leucocyte, gro enormously, and form large parasites, at first full of nuclei, and later o mono-nucleated merozoites, the whole process taking some twenty-six or mor days. The minute merozoites now enter the red corpuscles and grow int typical Halteridia. It appears that there are no trypanosome stages, and indeed, the only form of that nature met with was *Trypanosoma avium* Nov and McNeal.

This is quite a different history from that of Schaudinn for *H. noctuæ*

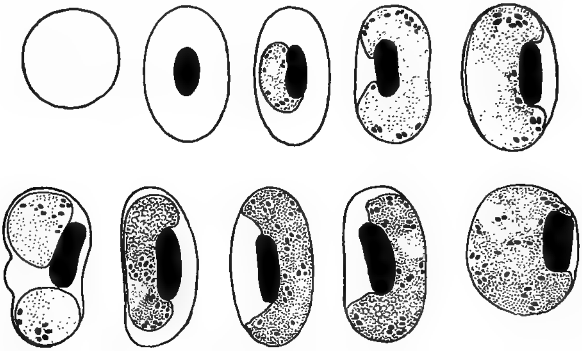

FIG. 65.—HÆMOPROTEUS COLUMBÆ CELLI AND SANFELICE.
(After Sambon.)

but it must be observed that it is incomplete, and, therefore, deduction cannot safely be drawn from it.

Other Species.—A large number of species are described by Celli an Sanfelice, Novy and McNeal and others, which have been found in birds a well as in some reptiles.

Sambon has recently described, under the name of *Hæmoproteus manson* (Fig. 55), a new species found in the red grouse (*Lagopus scoticus*), th gametocytes of which are not closely adherent to the nucleus of the erythrocyt as is usually the case, and sporogony takes place in a parasitic fly of th grouse (*Ornithomyia lagopodis*), in the stomach of which oökinetes were foun

FAMILY 2. LEUCOCYTOZOIDÆ.

Synonym—*Spiroschaudinnidæ Sambon* 1907, *pro parte.*—Acystina in whic the schizonts and gametocytes are alternately free and active, or endocellula and passive, the former being trypaniform and the latter amœboidal i appearance. The oökinete remains free, but increases in length, and afte coiling itself into a mass, gives rise to indifferent and sexual sporozoites.

There is only one genus known—*Leucocytozoön* Danilewskyi 1889—but number of species have been described, of which the life-history is bu imperfectly known, except in the case of *L. ziemanni*, which has bee

Leucocytozoön Danilewskyi 1889.

Synonyms. — *Hæmamœba* Laveran 1903, *Spirochæta* Schaudinn 1904, *Trypanomorpha* Woodcock 1906.

The leucocytozoa were first described by Danilewsky between 1884 and 1886 in the blood of the wood-owl (*Syrnium aluco*) and other Strigidæ.

He described them as spherical or oval, slightly granular bodies contained in a delicate transparent homogeneous capsule, which possessed a large elongated nucleus, compressed in the middle, and broadened at the extremities. This capsule he believed to be a degenerated leucocyte, but later he held it to be an erythrocyte. He also described macrogametes and motile oökinetes, and later he described the microgametocytes. In 1893 Sakharoff confirmed these observations and described new species in ravens, rooks, and magpies. In 1895 Theobald Smith discovered a leucocytozoön in *Meleagris gallopavo domestica* (the turkey); and in 1898 Ziemann described another specimen in *Glaucidium noctuæ* (the little owl) from Crema, in Italy. In 1902 and 1903 Laveran described forms in birds with mixed infections, and stated that he considered that they were contained in red blood cells. In 1904 Berestneff described several forms in owls, ravens, and magpies, but noted that they were in leucocytes; and in the same year came Schaudinn's paper on the development of *Leucocytozoön ziemanni*, which is given in detail later on. The Sergents, in studying the parasite in the little owl in Algeria, supported Schaudinn. In 1905 Laveran and Lucet studied Theobald Smith's parasite, and concluded that it was enclosed in a leucocyte. In 1906 Neave described a parasite in *Numidia ptilorhynca*; and in 1907 Sambon and Seligmann described one in *Lagopus scoticus* (the red grouse); and Dutton, Todd and Tobey another in *Asturinula monogrammica* (the Congo grey hawk); and lastly Sambon has quite recently reviewed the whole genus in a singularly able manner, and has described species from the capercailzie (*Tetrao urogallus*) and the pheasant (*Phasianus colchicus*).

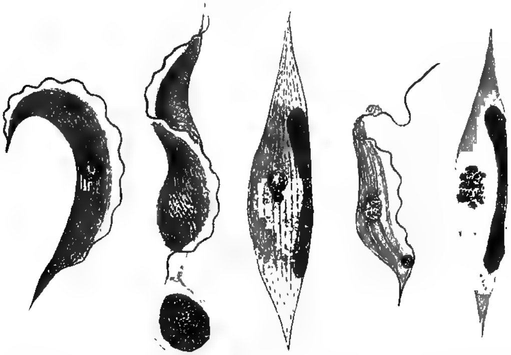

FIG. 66.—LEUCOCYTOZOÖN DANILEWSKYI ZIEMANN.
(After Schaudinn.)

From the left to the right, a macrogametocyte free, same attached to a blood cell, same enclosed in a blood cell; a free microgametocyte, same enclosed in a blood cell.

Leucocytozoön danilewskyi Ziemann 1898.

Synonyms.—*Hæmamœba ziemanni* Laveran 1902. *Spirochæta ziemanni*

ziemanni Lühe 1906. *L. danilewskyi* is found as a parasite in the hæmatobla (or, according to other authors, the leucocytes) of the little owl, *Glaucidiu noctuæ* (*Athene noctuæ* Retz) and the wood-owl, *Syrnicum aluco* L.

The history of the life-cycle, according to Schaudinn, may be begun wit the biting of the owl by *Culex pipiens* L., and the sucking of blood containin micro- and macrogametocytes.

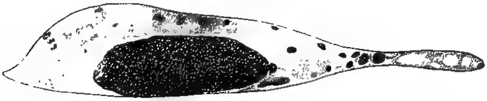

FIG. 67.—INTRACELLULAR FORM OF LEUCOCYTOZOÖN LOVATI.
(After Sambon.)

Microgametocyte.—The microgametocyte may attain dimensions muc larger than a leucocyte, and exists in the blood of the owl in two conditions (1) a free active stage in the liquor sanguinis; (2) endocellular resting stag in a blood cell; and later, when the parasite has become too large to penetrat a host cell, free in the blood stream. In this condition the parasite ma engulf the cells which formerly served it for food and shelter.

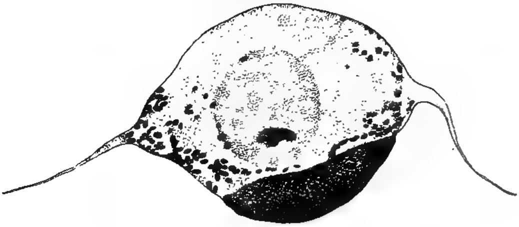

FIG. 68.—THE INTRACELLULAR MICROGAMETOCYTE OF LEUCOCYTOZOÖN LOVATI.
(After Seligmann and Sambon.)

(1) *Free Active Stage.*—This is the trypanosome stage (*T. ziemanni*). Th anterior end is sharp-pointed, with a kinetonucleus just at its base, from which the flagellum arises, passing posteriorly along the body and projectin some distance from the posterior end. There is a well-defined undulatin membrane, with sixteen myonemes arranged in four double rows or pairs o each side. The trophonucleus is well developed, and situate near the centr of the trypanosome.

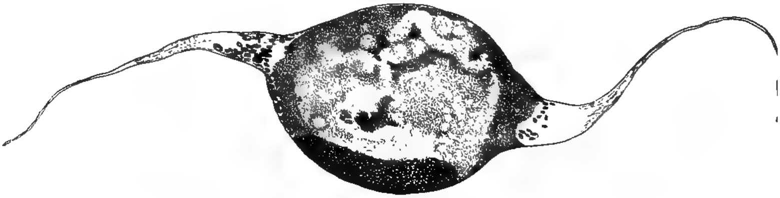

FIG. 69.—INTRACELLULAR MACROGAMETOCYTE OF LEUCOCYTOZOÖN LOVATI
(After Seligmann and Sambon.)

(2) *Endocellular Resting Stage.*—In the intracellular stage the parasite i quite spindle-shaped, the ends being composed of ectoplasm, while th endoplasm forms a dark oval central mass containing the trophonucleus

close to which the kinetonucleus is situated. The flagellum has disappeared, but the myonemes of the ectoplasm can still be seen.

Macrogametocyte.—This has also two stages—(1) free, (2) endocellular.

(1) *Free Active Stage.*—The free stage differs from the microgametocyte in being larger, in having no free projection of the flagellum, and in having smaller tropho- and kinetonuclei, and in the myonemes not being arranged in pairs.

(2) *Resting Stage.*—This differs from the microgametocyte in being large, with smaller nuclei.

These gametocytes, called 'leucocytozoön' by Danilewsky and 'hæmamœba' by Laveran, being found in the peripheral blood of the owl, are sucked into the stomach of *Culex pipiens*, and then proceed to conjugation.

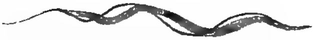

FIG. 70.—LEUCOCYTOZOÖN DANILEWSKYI ZIEMANN: MICROGAMETE.

(After Schaudinn.)

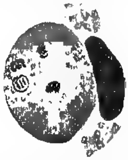

FIG. 71.—LEUCOCYTOZOÖN DANILEWSKYI ZIEMANN: MACROGAMETE.

(After Schaudinn.)

Microgamete.—The microgametocyte escapes from the capsule-like periplast, and its nucleus breaks up into eight double chromosomes, which are reduced to eight single chromosomes. These travel to the periphery, and form microgametes in the manner described for *Hæmoproteus noctuæ*, microgametes of which they are said to resemble.

Macrogamete.—The macrogametocyte escapes from its enclosing cell, and the process of development of the macrogamete is the same as in *Hæmoproteus*.

Fertilization.—This is the same as in *Hæmoproteus*.

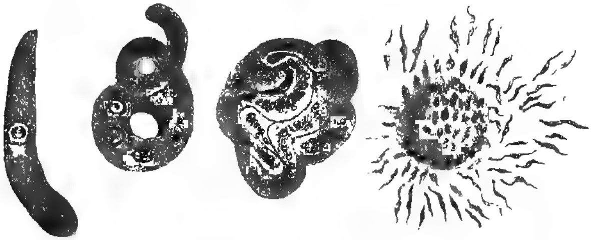

FIG. 72.—LEUCOCYTOZOÖN DANILEWSKYI ZIEMANN: THE DEVELOPMENT OF THE OÖKINETE AND THE FORMATION OF SMALL TRYPANIFORM BODIES.

(After Schaudinn.)

Oökinete.—There are the same three kinds of oökinetes as in *Hæmoproteus*—viz., the indifferent, the male, the female.

The oökinete, however, differs by growing in size and multiplication of its nuclei, and at the same time coiling upon itself so as to form a skein. This skein contains a large number of nuclei uniformly distributed.

Around each of these, small portions of protoplasm gather, and become finally separated off, to form small indifferent trypanosomes in the case of the indifferent oökinete, male trypanosomes from the male oökinete, female trypanosomes from the female oökinete. A large mass of residual protoplasm is left.

These trypanosomes, especially the male, are very minute, and reproduce by longitudinal division, during which they do not separate at once, but remain attached posteriorly. Couples attached to one another may extend into the same straight line, thus giving rise to a 'spirochæte-like form, and while in this position may undergo longitudinal division.' The spirochæte forms may become pear-shaped resting forms.

In the Owl.—On entering into the owl, the indifferent forms pass through alternate endocellular and free stages. In the former there is growth, and in the latter there is division into smaller forms. After some time micro- and macrogametocytes are formed in increasing numbers.

This life-history has been doubted, but Sambon has seen forms in which a coiled trypanosome body can be detected in the blood cells.

The Enclosing Cell.—There has been great doubt as to the character of the body enclosing a leucocytozoön.

1. Ziemann, Schaudinn, Dutton, Todd and Tobey believe that it is a portion of the parasite itself—*i.e.*, the periplast—and that it may enclose a red blood cell.

2. Danilewsky considers it to be a leucocyte, but derived his red cells from leucocytes. In considering it to be a leucocyte, he is supported by Laveran Lucet, Sakharoff, and Berestneff.

3. Laveran in his earlier observations believes it to be a red cell, and this Sambon supports.

It may be taken to be a much-enlarged dehæmoglobinized hæmatoblast or red cell, the spindle shape of which may be explained by the fusiform shape of the hæmatoblasts, and by the pseudopodia of the young parasites protruding into the long ends of the host cell. When the parasite contracts these ends shrivel up, giving rise to the usual appearance.

The Spirochætes.—At first Schaudinn, after tracing out the life-history described above, thought that all spirochætes would be found to be allied to true trypanosomes; but in 1905 he stated that the spirochæte-like forms which he found in the little owl were far removed from true spirochætes, and that the relationship was only phylogenetic, and very distant at that.

Species.—The species so far described are: *Leucocytozoön majoris* Laveran 1902, in the great tit (*Parus major*); *L. sakharoffi* Sambon 1908, in the raven (*Corvus corax*); *L. berestnieffi* Sambon 1908, in the magpie (*Pica pica*) *L. danilewskyi* Ziemann 1898, in the little owl (*Athene noctuæ*); *L. todd* Sambon 1907, in the Congo grey hawk (*Asturinula monogrammica*); *L. mansoni* Sambon 1908, in the capercailzie (*Tetrao urogallus*); *L. lovati* Sambon and Seligmann, in the red grouse (*Lagopus scoticus*); *L. macleani* Sambon 1908 in the common pheasant (*Phasianus colchicus*); *L. smithi* Laveran and Lucet 1905, in the domestic turkey (*Meleagris gallopavo domestica*); *L. neav* Balfour 1906, in the Abyssinian guinea-fowl (*Numidia ptilorhynca*).

FAMILY 3. TRYPANOSOMIDÆ SAMBON 1906.

Definition.—Encystina, with a well-developed flagellum and undulating membrane in some stage of the life-history. Th kinetonucleus passes forward, and in the fully developed flagellat stage is situate anterior to the trophonucleus. Schizogony take place by longitudinal division, but sporogony is as yet not properl known.

A brief history of the discovery of the more important species c the genus *Trypanosoma* has already been given in Chapter I., an all that need be said here is that in 1901 Laveran and Mesnil described a second genus, *Trypanoplasma*, and in 1904 Keysselitz third genus, *Trypanophis*.

The family therefore includes four genera: (1) *Trypanosoma* (2) *Trypanoplasma*; (3) *Trypanophis*; (4) *Endotrypanum*.

(1) Trypanosoma Gruby 1843.

Synonyms.—*Amœba* Gluge 1842, *Paramœcium* Gluge 1842, *Undulina* Lankester 1871, *Herpetomonas* Kent 1878, *Hæmatomonas* Mitrophan 1883, *Trypanomonas* Danilewsky 1885, *Trypanozoon* Lühe 1906.

Definition. — Trypanosomidæ, with the periplast raised into a longitudinal undulating membrane, along which the single flagellum runs.

Morphology.—The usual form in which trypanosomes are found in vertebrate blood is that of an elongated, spindle-shaped mass of cytoplasm composed of an inner granular endoplasm, and surrounded by ectoplasm (periplast). The shape of the parasite is, however, by no means always a spindle, but, on the contrary, varies considerably in different species, and may even be rounded.

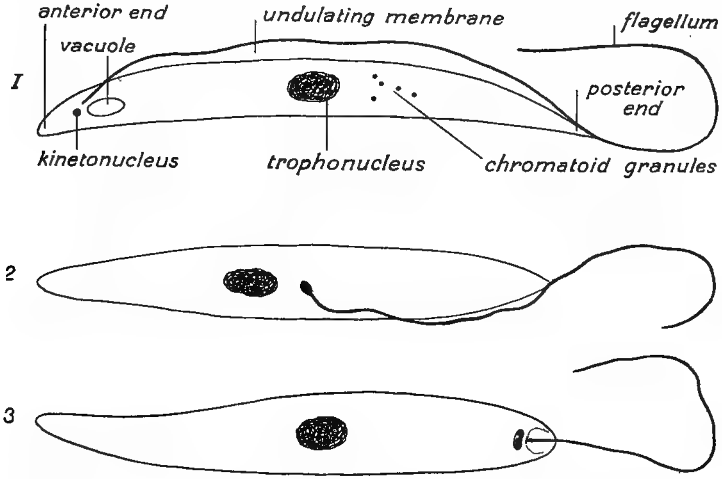

Fig. 73.—Diagram showing the Structure and Polarity of a Trypanosome.

1, Trypanosoma; 2, Herpetomonas; 3, Crithidia.

In the endoplasm is situated a trophonucleus, often called the 'nucleus,' concerning the structure of which there is considerable difference of opinion. Some authorities—*e.g.*, Prowazek, etc.—with regard to the nucleus of *T. lewisi* and *T. brucei*, and Miss Robertson, with regard to *T. raiæ*, say that the nucleus is complex and resembles the description already given for that of *Hæmoproteus noctuæ*, that of *T. lewisi* having eight chromosomes and a centrosome connected by a strand.

Other authorities, like Ross and Moore, Breinl and Hindle, consider that observers have been led astray by using dried films; for, according to them, though pretty pictures of the parasite are produced by this method, still, such delicate structures as the details of the nucleus are ruined, and therefore, in order to study these bodies accurately, the films must be fixed while wet in such a reagent as Fleming's fluid, and suitably stained. If this is done properly, according to them, it is seen that the nucleus is a vesicle bounded by a nuclear membrane, and having in its centre one smal chromatin sphere, called by some the intranuclear centrosome.

Situated somewhere in the cytoplasm, and generally near one extremity, is another mass of chromatin, by some looked upon as a kinetonucleus, and by others as simply an extra nuclear centrosome because they find no character of a nucleus, except the tendency to divide, in this body. From this kinetonucleus a faint strand proceeds, which ends in a little bead—the blepharoplast—from which the flagellum, which is also composed of chromatin, arises. The flagellum runs outwards through the endoplasm to the ectoplasm which it raises into a membrane, the undulating membrane, and turns, and, running along the remaining length of the cytoplasm projects as a free lash beyond the parasite. In this course it presents three portions: (1) The root in the endoplasm; (2) the undulating portion in the ectoplasm; and (3) the free portion. In some stages of the life-history the flagellum, instead of turning along the undulating membrane, projects from its blepharoblast through the endo- and ectoplasm to the outside of the parasite.

The undulating membrane, therefore, is the layer of ectoplasm (periplast) raised from the surface of the parasite by the second portion of the flagellum, and may be prolonged a certain distance along what is generally considered to be its free portion. The membrane is variously described as being homogeneous or strengthened by myonemes as in *Hæmoproteus noctuæ*.

Besides these structures the endoplasm often contains a vacuole looked upon by some observers as a contractile vacuole, while other deny its existence. There is no doubt about its existence in *Trypanosoma gambiense*. Chromatoid granules can also be seen in the cytoplasm.

Before leaving this part of the subject it must be noted that many authors have given various names to the trophonucleus kinetonucleus, centrosome, and blepharoplast. We use the terms in the same sense in which they have been used by Minchin and Woodcock—viz., the principal nucleus is a trophonucleus, because it is believed to be largely concerned in nutrition; it contains an achromatic body, which is the centrosome. The smaller nucleu is a kinetonucleus, because it is mainly concerned in motion; while the little bead connected with the flagellum is looked upon as a blepharoplast, because it is an achromatic body connected with a cilium or a flagellum.

We now come to a point on which there is a great difference o opinion—viz., the polarity of the parasite. There can be no doubt in our opinion, that, as a rule, the anterior end of a parasite should b the non-flagellate end, as first suggested by Sambon, because, in wending its way through the blood, that end goes first, and the undulating membrane and flagellum follow, and blood being the natural habitat of the parasite, this method of propulsion must be considered to be normal. Moreover, morphologists (Woodcock) support this view.

Movement is largely caused by the undulating membrane, while the flagellum assists; but creeping or gregarinoid movements have been noted by Léger, and zigzag movements by Gray and Tulloch, and in both of these the non-flagellate ends go first. In this work anterior, therefore, means the non-flagellate end of the trypanosome, and posterior the flagellate end.

The anterior end is very variable, and may be even amœboid, while the posterior end is generally tapering, because the cytoplasm extends some way along the flagellum.

It has already been noted that the body of the parasite is slightly compressed laterally, and the edge with the undulating membrane is considered to be dorsal.

The measurements of the parasite are from the non-flagellate extremity to the kinetonucleus, from that to the anterior end of the trophonucleus, from that to the posterior end of the trophonucleus, from that to the tip of the flagellum, the sum of these giving the length; while the width is taken in the region of the trophonucleus. Food is absorbed by osmosis from the liquid in which the parasite is living.

Schizogony.—The utmost confusion exists as regards the knowledge of the life-cycle in a vertebrate, and to Salvin Moore and Breinl, with Hindle, credit must be given for attempting to throw some light on the process.

Every observer is agreed that multiplication can take place by binary fission or by rosette formation.

Binary Fission.—Starting with a typical medium-sized parasite of *T. lewisi*, which is non-pathogenic, and therefore more likely to show the true life-history than a pathogenic species, Moore, Breinl, and Hindle have shown that a binary division takes place with or without growth. This is brought about by amitotic division of the kinetonucleus and trophonucleus, followed by the formation of a new flagellum in the daughter parasite and the division of the cytoplasm. They note the same method in *T. gambiense.* This is directly opposed to the observations of Prowazek and Byloff, who described complex nuclear divisions.

Rosette Formation.—The medium-sized parasite, according to Moore, Breinl, and Hindle, grows into large forms, which pass through the following development:

1. The trophonucleus undergoes reduction by amitosis, the reduction body disappearing.

2. The kinetonucleus gives off a body, which travels—increasing in size as it proceeds—to the trophonucleus, with which it perhaps fuses, but this is not definitely known.

In *T. gambiense* a strand forms between the kineto- and trophonuclei, instead of this travelling body, which is seen in *T. lewisi* and *T. equiperdum*.

3. The tropho- and kinetonuclei divide to form fusion masses consisting of two, four, seven, or more small parasites, which at first possess only the old flagellum, but in which later new flagella form (the rosette formation). This stage is not definitely known in *T. gambiense*.

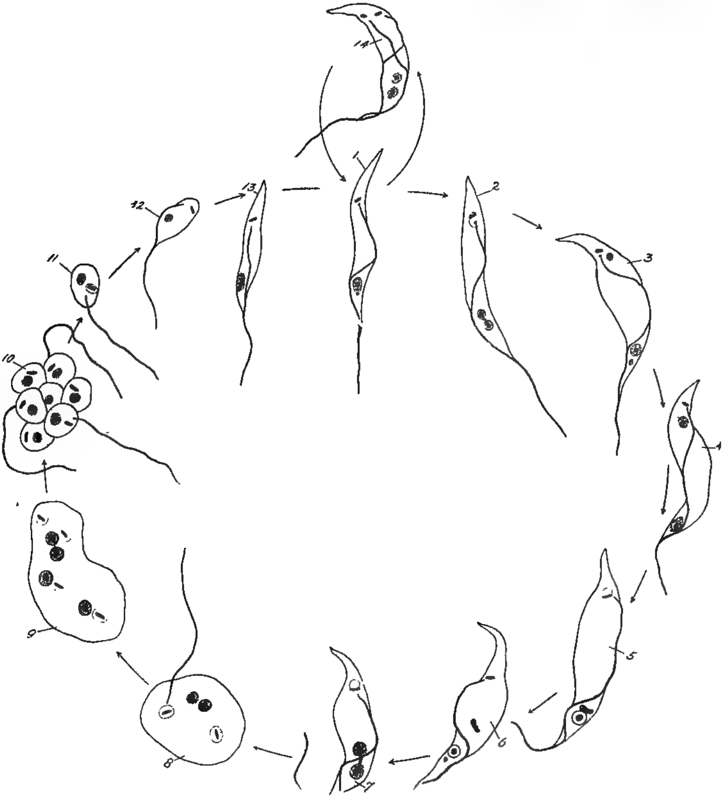

Fig. 74.—Diagram of the Life-Cycle of Trypanosoma lewisi in the Body of the Rat.

1, Trypanosoma lewisi; 2-10, stages in rosette formation; 11-13, development of a small flagellate form into a trypanosome; 14, binary fission.

(Constructed from drawings by Moore, Breinl, and Hindle in the *Annals of Tropical Medicine and Parasitology*.)

4. The small parasites, which must be looked upon as representing latent phases, separate from the fusion mass. These small parasites grow into medium-sized parasites, thus completing the cycle.

All observers are agreed as to the rosette formation, and with regard to the process from the kinetonucleus, this was first pointed out by Miss Robertson, whose work is therefore confirmed. The band is said to be composed of volutine. As to the latent phases, we believe that they are the same as the peculiar round and oval forms described several years ago by Castellani, in the cerebro-spinal fluid of sleeping-sickness patients, and which he compared to the amœboid forms found by Plimmer in the brains of animals infected with nagana.

Sporogony.—It has already been said that the utmost confusion exists as regards schizogony, which takes place in the vertebrate host, but the state of knowledge with regard to sporogony is almost worse. Theoretically, it would be expected that sexual forms, male and female, would be found in the blood of the vertebrate, and that these, taken into the alimentary canal of the blood-sucker, would conjugate and produce oökinetes, and perhaps oöcysts, from which forms would be produced which might infect the proboscis of the same individual, or, by entering into the eggs, infect a new generation, which alone might be the means of dissemination of the parasite. But these theoretical views have so far not been confirmed by actual observations, which must now be discussed seriatim.

Sexual Forms.—According to Prowazek, *T. lewisi* can be differentiated into three forms—(1) male, (2) female, (3) indifferent—and, according to Prowazek, Lühe, Nocht, and Mayer, the same can be seen in *T. gambiense ;* but according to Holmes, only males, females, and young females can be seen in *T. evansi.*

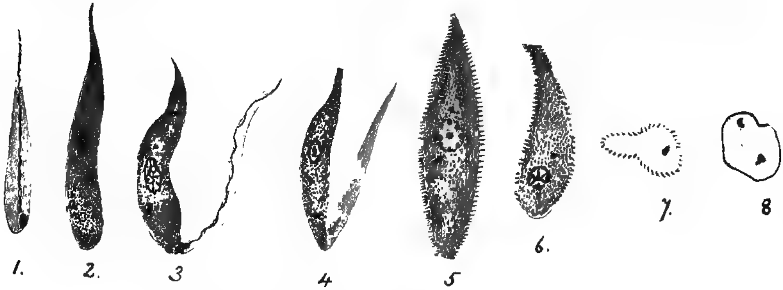

FIG. 75.—CRITHIDIA MELOPHAGIA FLU.
(After Flu.)

1, Microgamete ; 2, macrogamete ; 3, zygosis ; 4, oökinete and degenerating microgamete ; 5-8, oökinete in the alimentary canal and ovary.

Male Forms.—These are defined to be very slender trypanosomes, actively motile, with an elongated nucleus, which stains well.

Female Forms.—Broad, sluggish trypanosomes, with reticulated protoplasm and a round nucleus, both of which stain poorly, and they possess a slender, undulating membrane and a short flagellum.

Indifferent Forms.—These are the forms most commonly met possessing granular cytoplasm and a not very well defined nuc

It must be admitted that between these there are all stag intermediary forms, so that they are not sharply defined. Kleii his recent study of *T. gambiense*, in *Glossina palpalis* describes male and broad female forms in the fore and hind gut, and forms which closely approach the *T. gambiense* of mamm blood in the fore gut and proventriculus. He is inclined to be in sexual reproduction during the resting stage. A partial dev ment has at times been observed by Kleine in *G. morsitans*, bu insects never became infective.

Conjugation.—Conjugation of male and female forms has but seldom observed, and, indeed, it is difficult to be certain it is conjugation which has been seen, and not division. How it has been described by Keysselitz as occurring in leeches fe a carp infected with *Trypanoplasma borreli*, and by Prowazek ir fed on rats infected with *T. lewisi*. The most convincing acc is that by Flu in *Crithidia melophagia*, to which reference wi made under the heading Crithidia.

On the other hand, careful observers like Miss Robertson Captain Patton have quite recently failed to see this process in studies of trypanosomes and herpetomonads. The conclusio that although conjugation, according to our ideas of a life-c must take place, it certainly has not been proved to be preseı trypanosomes so far, though it may at any time be establi definitely.

Oökinete.—Oökinetes, which, though binucleate, did not po a locomotive apparatus, have been observed by Léger in lee fed upon loach infected with *T. barbatulæ*, and these seen correspond to forms seen by Miss Robertson and Brumpt as earliest stage of the development of *T. rajæ* in *Pontobdella muri* and are by no means unlike the encysted forms described by chin, Prowazek, and Flu in *T. grayi*, *H. muscæ-domesticæ*, *C. melophagia* respectively.

Further Development.—According to Miss Robertson, the t cleate forms mentioned above develop into a number of herı moniform parasites of varying shapes and sizes, according to activity of multiplication, but ultimately the whole alimen canal (including the proboscis) becomes occupied by herpeton form or trypaniform parasites (which develop from the herı moniform parasites) to the exclusion of other forms. When t are injected into the vertebrate host they multiply, and fiı grow into adult trypanosomes. These observations of Miss Rol son on the development of the trypanosomes in leeches fe infected fish and tortoises are very suggestive, and are, in paı least, supported by the observations of Stuhlmann, who f trypanosomes developed from *T. brucei* in the proventriculu *Glossina fusca*, and are confirmed by the discovery of slender f in the œsophagus of tsetse-flies caught wild.

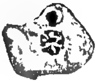

FIG. 76.—TRYPANOSOMA RAJÆ: ROUND FORM, IN THE LEECH.
(After Miss Robertson.)

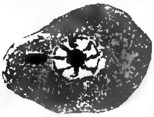

FIG. 77.—TRYPANOSOMA RAJÆ: ROUND FORM, OLDER STAGE.
(After Miss Robertson.)

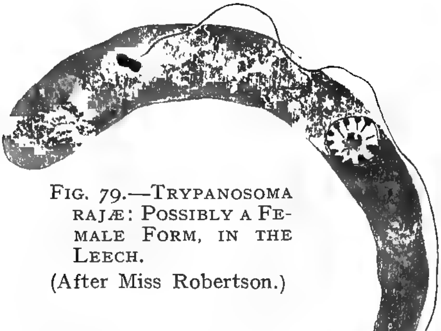

FIG. 79.—TRYPANOSOMA RAJÆ: POSSIBLY A FEMALE FORM, IN THE LEECH.
(After Miss Robertson.)

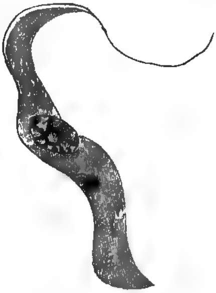

FIG. 78.—TRYPANOSOMA RAJÆ: YOUNG TRYPANOSOME IN THE LEECH.
(After Miss Robertson.)

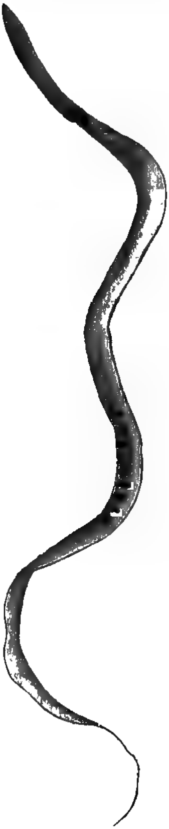

FIG. 80.—TRYPANOSOMA RAJÆ: POS-

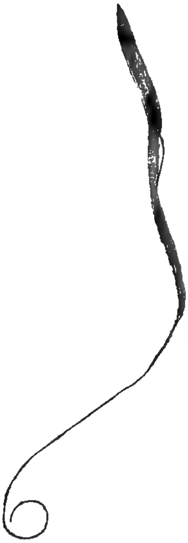

FIG. 81.—TRYPANOSOMA RAJÆ: SLEN-

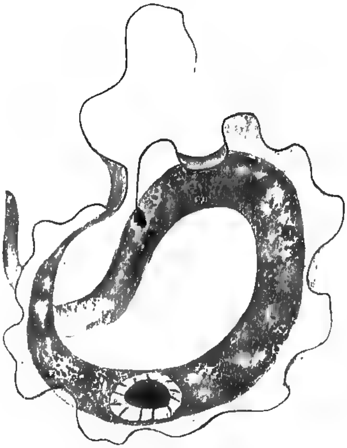

FIG. 82.—TRYPANOSOMA RAJÆ: FULLY DEVELOPED TRYPANO-

Minchin has described a different method of developmen which the herpetomoniform parasites of *T. grayi* in *Glossina pal* develop into the binucleated encysted forms mentioned abo possible oökinetes. These forms he considers pass out in the f

A third method of development is described by Flu, who, th he is unable to follow the stages immediately succeeding the oök of *C. melophagia*, still considers that forms arise which infec eggs of the *Melophagus ovinus*, and probably spread the infe to the next generation of these insects.

Asexual Development in the Invertebrate Host.—Roubaud described a form of asexual development of *T. gambiense T. brucei* in the proboscis of *Glossina palpalis* in which undulating membrane disappears; this flagellum is shortened, the kinetonucleus approaches the trophonucleus, while the par becoming attached to the wall of the proboscis, multiplies, for masses of parasites, the whole process occupying only a few min

Though he thinks that this method of development explain infection of man and animals by tsetse-flies in Africa, he unable to produce infection of susceptible animals by inocul of these forms.

Effects upon the Host.—Trypanosomes may produce patholo effects on their host, or may apparently be harmless.

The best known of the former are: *T. gambiense*, the cau sleeping sickness; *T. cruzi* of American trypanosomiasis; *T. ev* of surra in horses, etc., in India and elsewhere; *T. brucei*, of na in cattle and horses, etc.; *T. vivax*, of disease in cattle, sheep, goats, in the Cameroons; *T. nanum*, of cattle sickness in the A Egyptian Sudan; *T. dimorphon*, of the Gambia horse sick *T. cazalboui*, of souma, a disease of cattle in the French Sudan, *T. pecaudi*, of sheep in the same place; *T. equinum*, of m caderas in South America; *T. equiperdum*, of dourine in hors Europe and Africa.

Symptoms.—The pathogenic effects of the parasites show t selves in the production of fever, skin eruptions, emaciation, or general œdema, and disease of the nervous system. Secon bacterial affections are also common. The mortality is often

Morbid Anatomy.—The lesions are often insignificant, but in mation and enlargement of the lymphatic glands is character and dropsy and inflammation of the meninges are also f which in human trypanosomiasis takes the form of men encephalitis, as will be described later.

Agglutinins.—While in the body of the host agglutinin formed, for if blood containing trypanosomes is treated wit serum of an animal which has had one or more injections of containing the same parasite, a rapid massing of the parasites rosettes, with the anterior ends pointing inwards and the fl outwards, takes place.

This is called agglomeration, and may last a few minutes parasites being unaffected, or may persist till they die.

Precipitins.—Mayer has shown that the serum of a dog infected by *T. brucei* is precipitated by a salt extract of the same parasite, but not by that of *T. equinum*, thus proving the presence of specific precipitins.

Inoculations.—The parasites can be spread from one animal and from one species to another by inoculation of infected blood.

Immunity.—Active immunity, due to the action of the leucocytes (Laveran and Mesnil) or to cytolysins (McNeal), can be produced in certain cases, but it is not carried from mother to young.

Passive immunity was produced by Rabinowitsch and Kempner for *T. lewisi*, and is either wholly or partially successful. Natural immunity is well known—*e.g.*, man against *T. brucei.*

Involution Forms.—Degenerated, vacuolated involution forms may be seen as a result of immunity coming on, or of treatment by drugs.

Cultivation.—McNeal and Novy cultivated *T. lewisi* in the water of condensation of blood-agar tubes in 1903, and obtained at 37° C., and also at the room temperature, good cultures, in which *T. lewisi* varied in size from minute forms 1 to 2 μ in length up to 50 to 60 μ, and colonies of rosettes were seen with all the flagella turned inwards. The flagellum in cultivated forms projects directly from the kineto-nuclear end of the parasite.

The following have been cultivated: *T. cruzi*, by Chagas; *T. brucei*, by McNeal and Novy, and by Laveran and Mesnil; *T. equinum*, by R. Thomas and Breinl, *T. equiperdum*, by Thomas and Breinl, with slight success; *T. gambiense*, by Thomas and Breinl and Gray and Tulloch, with partial success; *T. evansi*, by Novy, McNeal and Hare, and by Thomas and Breinl, but were found to be non-virulent, and subcultures could not be obtained.

Infection.—In nature there can be no doubt that infection can take place in more than one way, and Minchin has pointed out that the different methods may be:—

1. The swallowing of encysted parasites.
2. Conveyance from one vertebrate host to another by some blood-sucking invertebrate animal, either directly or indirectly.

1. CONTAMINATIVE.—This is the infection of the host by swallowing encysted parasites. At present there is no proof that this exists in trypanosomes. But Minchin has shown that *T. grayi* becomes encysted while lying in the proctodæum of *Glossina palpalis* by a shortening of the flagellum and an excretion of a cyst-wall, which, beginning at the anterior extremity, gradually spreads round the shortening parasite while the flagellum is being absorbed. The cysts, which lie quite free in the proctodæum, are first pear-shaped and then oval, and the trophonuclei and kinetonuclei break up into chromidia. Minchin believes that these cysts will be found to infect some vertebrate, but there is no proof of this at present.

2. INOCULATIVE.—The spread of a trypanosome from one vertebrate host to another was demonstrated by Bruce while studying *T. brucei*, and also by the same observer, Nabarro, and Kleine for

T. gambiense, both diseases being spread by tsetse-flies, though regard to the former it had long been known that the tsetse-fly the cause of the disease.

There are, however, two ways in which a blood-sucker can sp an infection: (*a*) the direct; (*b*) the indirect.

(*a*) *The Direct.*—In this the blood-sucker simply transmits parasite unchanged.

(*b*) *The Indirect.*—In this method the parasite undergoes a c of development in the blood-sucker, the nature of which has l fully discussed already.

Classification.—The various species of the genus *Trypanosoma* differentiated by—(1) their morphological characters; (2) t animal reactions, which are (*a*) the effects of inoculation into ferent animals, some of which will be found to be immune; (*b*) effect of cross-immunization, which means that an animal immun against one species of trypanosome will be found open to attacl another; (*c*) agglomeration caused by immune serum; (3) atten at cultivation on the Novy-McNeal-Matthias medium will di entiate certain forms which develop in different ways, while ot will not develop at all; (4) application of the precipitin test; (5) discovery of the true invertebrate host; (6) the chromotherape reactions, for Mesnil and Nicolle have shown that different der tives of benzine have varying effects on pathogenic trypanoso and may therefore help to differentiate them.

TRYPANOSOMES OF MAMMALS.

Trypanosoma lewisi Kent 1879.

Synonyms.—*Herpetomonas lewisi* Kent 1880; *Trichomonas le* Crookshank 1886; *Trypanomonas lewisi* Labbé 1891; *Trypanos sanguinis* Kanthack, Durham and Blandford 1898; *T. ratto* Börner 1901; *Trypanomonas murium* Danil 1899; and *Trypano lewisi* Lühe 1906.

T. lewisi was the first mammalian trypanosome to be discove for it was seen by Chussat in 1850 in *Mus rattus* (probably no Gros in 1845), who thought it was a young nematode, while Le in Calcutta, in 1877, rediscovered it, and recognized that it wa protozoön. It is a typical trypanosome, and is found in *rattus* L., *M. norvegicus* Pall, and *M. rufescens* Gray all the world—in Asia (India, Ceylon, Java, Philippines, Japan) Europe (England, Ireland, France, Holland, Germany, Rus in Africa (Uganda, Abyssinia, Gambia, and Cameroons), and America (United States and Brazil). It is nonpathogenic, restricted to rats, among which it is probably spread by *Hæm pinus spinulosus*, the rat louse, and *Pulex fasciatus*, the rat flea.

It is a very active, worm-like little parasite darting about am the corpuscles. It is 24 to 25 μ in length and 1·5 μ in breadth. anterior end is very pointed, and the whole parasite is thin.

trophonucleus is situated near the junction of the middle and posterior thirds of the body, and the kinetonucleus, which is rod-shaped, is situated anteriorly. There are eight myonemes in the ectoplasm (periplast). Prowazek distinguishes small male forms with a nucleus rich in chromatin, large female forms with clear cytoplasm, and indifferent forms with many granules and poorly defined nucleus. The life-history in the rat has been worked out by Breinl and Hindle, as already described above (p. 249). The filament they mention as occurring between the kinetonucleus and the trophonucleus appears to have been also seen by Prowazek. Asexual reproduction may be summarized into reproduction with longitudinal division and reproduction with rosette formation and encystment after some interchange between the kineto- and trophonuclei, followed in due course by increased power for longitudinal division. Battaglia describes a process of sporogony with the formation of macro- and microgametocytes, and of macrogametes and microgametes, and a similar reproduction has been described by Pricolo.

In the louse the life-cycle has been studied by Prowazek, who finds that the micro- and macrogametocytes undergo first a reduction of the trophonucleus from sixteen chromosomes to four, and that then the microgametocyte gives rise to only one microgamete, which fuses with the macrogamete, forming an oökinete. This becomes a trypanosome by the separation of the kinetonucleus from the synkaryon.

The flagellum projects from the posterior end, which the kinetonucleus now leaves, and, taking the flagellum with it, proceeds towards the anterior end, thus forming the undulating membrane. Gregariniform non-flagellate forms also appear, which penetrate between the epithelial cells.

Prowazek failed to infect rats by the bite of the louse, but this has been done successfully by Rabinowitsch and Kempner with *Pulex fasciatus*. Nuttall has recently proved that *T. lewisi* can be transmitted from rat to rat by the fleas *Ceratophyllus fasciatus* and *Ctenophthalmus agyrtes*, and by the louse *Hæmatopinus spinulosus*. He therefore considers it doubtful that this flagellate is a true parasite of the invertebrate host.

Cultural experiments have been carried out successfully by Novy and McNeal on a medium prepared by mixing agar and defibrinated rabbit's blood in equal parts, when forms from 1½ to 60 μ in length may be found, and also rosettes, but the forms are herpetomoniform, with the kinetonucleus at the posterior end.

Inoculation can only be carried out successfully in rats, in which it is generally non-pathogenic, though rarely some observers have described dyspnœa, œdema, and subcutaneous hæmorrhages in intense infections.

Immunity is gained when a rat becomes free from the parasites, and hyperimmunity can be obtained by inoculations. It is thought that the immunity is largely due to phagocytosis, but this is being questioned in many species of trypanosomes. A protective serum is obtainable from hyperimmune rats. Immune serum will a merate the trypanosomes. The parasites cannot be transm from the mother to young, as it appears that they cannot tra the placenta.

Trypanosoma evansi Steel 1885.

Synonyms.—*Spirochæta evansi* Steel 1885, *Hæmatomonas e* Crookshank 1886, and *Trichomonas evansi* Crookshank 1886.

Trypanosoma evansi, discovered by Evans in India in 18 the cause of a disease called surra, which occurs in horses, n camels, and cattle in India, Burma, Indo-China, Java, Philipp Mauritius, and North Africa. With regard to cattle, they supposed to be immune until the outbreak in Mauritius in which killed from 25 to 100 per cent. of the infected cattle.

This trypanosome, 25 μ in length and 1·5 μ in breadth, has a po anterior extremity, a long flagellum, and is actively motile reproduces asexually by simple division.

Holmes recognizes male and female forms, which he considers jugate by the anterior extremities only, after which the female di forming four amœboid bodies, which, in the liver, spleen, and marrow, develop into trypanosomes. This appears to some resemble the descriptions of Breinl and Hindle of latent forn *T. gambiense*. *T. evansi* can be cultivated, and appears to de in certain flies—for example, *Tabanus tropicus*, *T. lineola*, *Sto calcitrans*, *S. geniculatus*, in the stomach of the last of whi has been found. Certainly it can be transmitted to healthy an by the bites of flies and fleas. It is said that it can also be contr by eating infected meat.

The symptoms are fever, remittent or intermittent, emacia œdema of the limbs and ventral surfaces, frequently lesions o eyes and eyelids, great muscular weakness, paralysis, and d The treatment is by arsenic.

Trypanosoma brucei Plimmer and Bradford 1889.

This parasite was discovered by Colonel Sir David and Lady in 1895 in animals suffering from the tsetse-fly disease or na (which means 'weakness') in Zululand. At the same time showed that the tsetse-fly (*Glossina morsitans*) disseminated the di

The parasite is widespread throughout Africa, especially in land, Northern Transvaal, and its surrounding countries; also Pretoria to Lake Nyassa, in the basin of the Limpopo, in the of the Zambesi, in German East Africa, British East Africa, it causes nagana or the fly disease, and in Uganda, where it is 'jinja.'

The appearance of the parasite is worm-like, being 28 to 3 length in horses and donkeys. The length is constant for the animal, but varies in different hosts, being 26 to 27 μ in rats, guinea-pigs, rabbits, and dogs. The anterior end (non-flage is a truncated cone, behind which lies the kinetonucleus as a well marked rounded mass, posterior to which the flagellum arises. Th trophonucleus lies in the middle of the body, and many chromatoi granules may be seen posterior to it, while still further posterio the free whip of the flagellum may be noted. Koch consider *T. brucei* to be identical with *T. evansi*, but the animal reaction clearly show them to be different species.

The life-cycle in the vertebrate host has not been very full worked out, but the longitudinal division is well known. Th kinetonucleus divides first, then the flagellum, then the trophc nucleus, and finally the cytoplasm, but, according to Prowazel division is really a very complicated process. First the blepharc plast becomes thickened, elongated, and dumb-bell-shaped, and the divides. In the trophonucleus the chromosomes behave like th kinetonucleus and the centrosome, and, having divided, the whol nucleus divides. The chromatin granules in the cytoplasm are als said to undergo fission, while a new flagellum develops from th new kinetonucleus. Parasites resembling the latent forms of Breir and Hindle are known, and are called involution forms.

In the tsetse-flies *Glossina morsitans*, *G. pallidipes*, and especiall *G. fusca*, Koch finds large female forms and small male forms, an in the posterior part of the stomach large forms with several trophc nuclei and only one kinetonucleus and one flagellar apparatu which are believed to be fertilized females. These are believed t give rise to herpetomoniform parasites, which invade the probosci where trypanosomes in all stages of development can be foun But it is only those which are like the trypanosomes of the bloc which infect the animal.

Novy and McNeal have cultivated *T. brucei* in the same mann as *T. lewisi*, and found some evidence of a toxin, but it only grov exceptionally in the water of condensation from the agar mediu which contains half or less than half its volume of blood. Aggl meration takes place under various circumstances—*e.g.*, mixtu with immune blood or a few drops of dilute acetic acid, etc.

It is believed by some authorities that the parasite lives in natu in the wildebeeste (*Catoblepus gnu*), the koodoo (*Strepsicer capensis*), the brush-buck (*Tragelaphus scriptus sylvaticus*), and tl hyena, without causing disease. These may form a reserve fro which the tsetse-flies *G. morsitans*, *G. pallidipes*, and *G. fusca* ca obtain parasites which undergo development in their alimenta canal, during which time they are non-pathogenic, and when ful developed are found in the proboscis, and are again capable of bei inoculated into animals, in some of which they are pathogen Kleine has proved that the transmission of the trypanosome is n merely mechanical, as suggested by Bruce and others, but also tak place after the trypanosome has undergone development in the f which is its true host. Thus, freshly caught *Glossina morsitans* f the first three days infected cattle, and then, from the fourth to t tenth day the flies were non-infective, but from the eleventh to tl forty-fourth day they were very infective. This shows that the parasite must undergo a development in the fly.

The disease can therefore be spread by the bites of certain tsetse-flies, particularly *G. morsitans* and perhaps the others mentioned above.

It can, however, be also spread by inoculation and by eating the blood of animals recently dead from the disease.

The incubation period is about ten days, and the effects produced in animals vary considerably in the following manner:

1. It is an acute disease in mice, rats, dogs, monkeys, cats, etc., dogs dying in two to six days, rats in three to six days.
2. It is a subacute disease in rabbits, guinea-pigs, equines, and pigs, a horse dying in fifteen to ninety days.
3. It is a chronic disease in cattle, goats, geese, and fowls. In cattle it lasts from one week to six months.

Battaglia has succeeded in inoculating bitches by injecting some infected blood *in vaginam.* He has also infected rabbits by inoculating blood on the penis, when a hard, granulomatous nodule, very similar to a human syphilitic primary sore, developed.

Nagana is invariably fatal to the horse, the ass, and the dog, but a small percentage of bovines recover.

It is characterized by fever; by an infiltration of coagulable lymph in the subcutaneous tissue of the neck, of the abdomen, or of the extremities, giving a swollen appearance to those parts; by a destruction more or less rapid of the red corpuscles of the blood, with an extreme emaciation, often blindness; and by the presence constantly in the blood of *T. brucei.*

Very few lesions are found at the autopsy, the most characteristic being:

1. Enlargement of the spleen.
2. Trypanosomes in the blood.
3. Hypertrophy of the lymphatic glands, but apparently not associated with a development of the parasites in these organs.
4. In horses, the liver and spleen are hypertrophied, and there is yellow serous infiltration under the skin and mucosa and between the muscles, as well as some pleural and pericardial exudations and sub-pericardial ecchymoses.
5. In a pig which had shown paralytic symptoms the vertebræ of the spinal column were osteomalacic, and the posterior part of the spinal cord was surrounded by a gelatinous substance like that which had coagulated in the tissues.

The best treatment is arsenic in some form. Trypanroth, a benzine colour, and serum treatment have not proved of great service.

Trypanosoma dimorphon Laveran and Mesnil 1904.

This trypanosome was discovered by Dutton and Todd in 1904 in horses on the Gambia, and is now known to exist in several parts of Africa, where perhaps a wide equatorial belt across the continent is affected. It is also found in cattle, dogs, pigs, sheep, and goats.

It exists in three forms:

1. *Tadpole Form.*—Found in the early stage of the disease, 11 to 13 μ long and 0·18 μ broad.

2. *Stumpy Form.*—Seen when the disease is not too far advanced, and characterized by a short thick body and a short flagellum. Length 16 to 19 μ, breadth 3·4 to 3·5 μ.

3. *Long Form.*—With long thin body and long flagellum, found a few days before death. Length, 26 to 30 μ; breadth, 1·6 to 2 μ.

These may be respectively indifferent, female, and male forms of the parasite.

It has been cultivated. It may perhaps develop in *Glossina tachinoides* Westwood, which is the common tsetse-fly of the Gambia, or in *G. palpalis.* It can be inoculated into rats, mice, guinea-pigs, and rabbits, as well as horses.

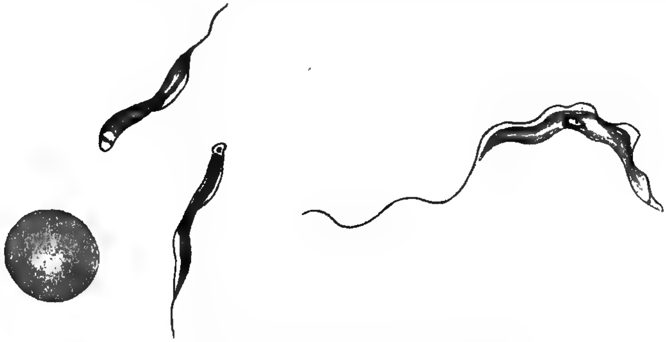

FIG. 83.—TRYPANOSOMA DIMORPHON.
(After Dutton and Todd.)

The symptoms in the horse begin with loss of vigour, followed in two to three weeks by fever. During the next month the weakness is more marked and the abdomen swells, the testicles hang down and are œdematous, the coat becomes staring, the animal looks apathetic, and death ensues in about a year.

The post-mortem shows œdema of the abdominal wall and a coloured fluid in the pleura and pericardium, with hypertrophy of the lymphatic glands, fatty liver, and congestion of the lungs. The spleen is normal.*

Trypanosoma equinum Vosges 1902.

Synonym.—*T. elmassiani* Lignières.

T. equinum, discovered by Elmassian, is the cause of mal de caderas in horses and dogs in South America.

This parasite closely resembles *T. brucei* and *T. evansi.* In length it is 22 to 24 μ, and in breadth 1·5 μ, and it has the same measurements in different species of animals. It is very active, but its principal characteristic is that the kinetonucleus is very insignificant.

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* It would appear from recent publications that different species have been confused under the term *T. dimorphon.*

Multiplication is by equal binary division. It agglomerates, and has been cultivated by Thomas and Breinl on a rabbit's blood and chicken-broth agar medium.

It can be inoculated into the ordinary laboratory animals. Its mode of propagation is not well known, and seems to bear some relationship to a disease which kills the capybara (*Hydrochærus capybara*), which appears to be the reservoir for the parasite. Dogs may be infected by eating diseased animals, and then from the dog the infection may be spread to the horse by fleas, because they have been found to infect rats. Authorities consider that it may be spread by members of the Tabanidæ and by *Stomoxys*.

Mal de caderas is a very fatal disease among the horses of South America. The first sign of the disease is weakness, which makes rapid progress, though the appetite remains good. The temperature is febrile, and after a variable period the hindquarters become paralyzed and the horse drags its limbs, the hoofs scraping the ground. As it walks it staggers, the hindquarters oscillating from right to left, which characteristic gives the disease its name of mal de caderas, the disease of the hindquarters. In the stable it can support itself against the walls, but in the open air it staggers and falls. There may be albuminuria and hæmaturia and an eruption on the neck, shoulders, and hindquarters. The eyelids show conjunctivitis and chemosis.

The horse lives about two months after the paralysis sets in.

Congestion and enlargement of the spleen and mesenteric glands are seen in post-mortems. The kidneys are affected, nephritis and interstitial hæmorrhages being noted. There are also serous exudations into the peritoneum, the pleura, the pericardium, and the spinal canal.

Trypanosoma equiperdum Doflein 1901.

Synonym.—*T. rougeti* Laveran and Mesnil.

T. equiperdum is the cause of the disease called dourine or mal du coit in horses in Europe, India, North Africa (Algeria), and North America. It is about 25 to 28 μ in length, and has no chromatic granules in the cytoplasm. It is difficult to find in naturally infected animals, being best obtained from the plaques of the eruption. It does not appear to be spread by a fly, but by coitus between stallion and mare. Hence the disease resembles syphilis, and proves that a trypanosome is capable of penetrating a mucous membrane. The incubation is from eleven to twenty days, after which the genital organs begin to show signs of œdema, generally painless and not inflammatory, though there is some fever. In about a month the œdema disappears, and weakness and emaciation begin. This is *Stage* 1, *or the period of œdema.*

Stage 2, *or the period of eruption*, is characterized by the appearance in about forty to forty-five days (or two months) after infection of an eruption, characterized by circular œdematous areas about the size of a two-shilling piece generally under the skin of the sides and hindquarters, but sometimes also under that of the neck, shoulders, and thighs. This eruption is very variable, and may appear in the morning and disappear at night, but generally it lasts a week, and leaves the animal in a feeble condition. There is also synovial engorgement of the joints and tendon-sheaths, and enlargement of the lymphatic glands, particularly the inguinal. The temperature is often raised to 39° C. (102·2° F.) in the evening, and falls to 38·5° C. (101·4° F.) in the morning.

Stage 3, *or the period of anæmia and paralysis*. The animal now becomes very anæmic, with pale mucosæ, and emaciation is marked. There are often superficial abscesses which do not heal, and some conjunctivitis and ulcerative keratitis. Micturition is difficult, and the urine is thick. Sensibility is diminished, and paralysis comes on, due to softening of the cord, and in from two to eighteen months the animal dies. The disease is said to be always fatal.

The above is the usual type of the disease, and may be called chronic dourine, but in addition there is an acute type, in which the animal dies after the first stage from acute paralysis, which comes on suddenly a few days after the appearance of the eruption.

The post-mortem lesions are in the spinal cord and the lymphatic glands. In the cord there is gelatinous exudation around the lumbar area, and cervical enlargement with intense chronic inflammation of the posterior spinal ganglia, with degeneration of the perikarya and their associated neurones, causing degeneration of the posterior roots and columns, as in tabes dorsalis.

The grey matter of the cord also shows chromolytic changes, with capillary hæmorrhages due to chronic inflammation. Mott says that the infiltration and thickening of the septa of the cord, the infiltration of the nerve roots and the vessel walls with lymphocytes, is like a syphilitic meningitis. The membranes at the base of the brain may also be affected. The lymphatic glands are enlarged, congested, and softened. The disease appears to begin by inoculation, and then to spread to the inguinal glands, and then to the pelvic lymphatics, and from them to the posterior lumbo-sacral roots, and thus the cord becomes affected. Other lesions are gelatinous exudation under the skin, serous effusions into the pleural and peritoneal cavities, wasting and pallor of muscles, with fatty degeneration and an interstitial keratitis.

Trypanosoma theileri Bruce 1902.

Synonym.—*T. transvaaliense* Laveran 1902.

T. theileri is probably the cause of galziekté, or gall sickness, in cattle in the Transvaal, in Togoland, German East Africa, Transcaucasia, and in India. It is of large size, 60 to 70 μ in length and 4 to 5 μ in breadth. A small form is known, 25 to 53 μ in length and 2 to 3 μ in breadth. It moves very rapidly, and has a long flagellum, while the anterior end is pointed and the kinetonucleus is oval. Multiplication is by simple longitudinal fission. A female form has been described by Lühe. It is believed to be spread by species of Hippobosca, and is specific for bovines, not being inoculable into other animals.

The disease, which may be acute or subacute, begins after an incubation of three to five days with fever, and sometimes severe anæmia, with leucocytosis and basophilia, develops, which is often complicated by babesiasis or spirochætiasis.

Post-mortem reveals anæmia and icteric staining of the tissues, and enlargement of the lymphatic glands of the mesentery.

Trypanosoma gambiense Dutton 1902.

Synonyms.—*T. nepveui* Sambon 1903, *T. hominis* Manson 1903, *T. castellanii* Kruse 1903, *T. ugandense* Castellani 1903, *T. fordii* Maxwell 1903.

T. gambiense was first found by Forde in the Gambia in a peculiar case of fever. He showed it to Dutton, who described and named it. The trypanosome had, however, been seen and imperfectly described previously by Nepveu in the blood of man.

T. gambiense was first seen in the cerebro-spinal fluid of cases of sleeping sickness by Castellani in 1902, and reported by him as the cause of the disease in 1903. Bruce and Nabarro demonstrated the fact first suggested by Sambon and Brumpt that it could be spread by a tsetse-fly, *Glossina palpalis;* and Kleine has demonstrated that the transmission is not merely mechanical, but also takes place after a period during which the fly is non-infective, the deduction being that the trypanosome must undergo a development in the fly which acts as a true host.

Morphology.—*T. gambiense* measures from 16 to 24 μ in length and from 2 to 2·5 μ in breadth. (Laveran and Mesnil give 17 to 28 μ in length and 1·4 to 2 μ in breadth.) The anterior end is variable and sometimes rounded; the kinetonucleus is an oval body, behind which is often seen a vacuole. The trophonucleus is oval in shape, and situated about the middle of the body, behind which there may be some chromatic granules in the cytoplasm, which at the posterior end runs along the flagellum for a considerable distance.

Asexual Reproduction.—The life-history of the parasite in the human body is not accurately known. It can often be obtained from the peripheral blood, but sometimes the most prolonged search fails to demonstrate it. It can then be found by puncturing the enlarged lymphatic glands, by scarification of the eruption, or by puncture of the spinal canal, if the case is one of sleeping sickness.

Salvin, Moore and Breinl have, however, investigated the life-cycle in the rat, in which, after inoculation, the parasites increase to a maximum in the peripheral blood, and then decline gradually

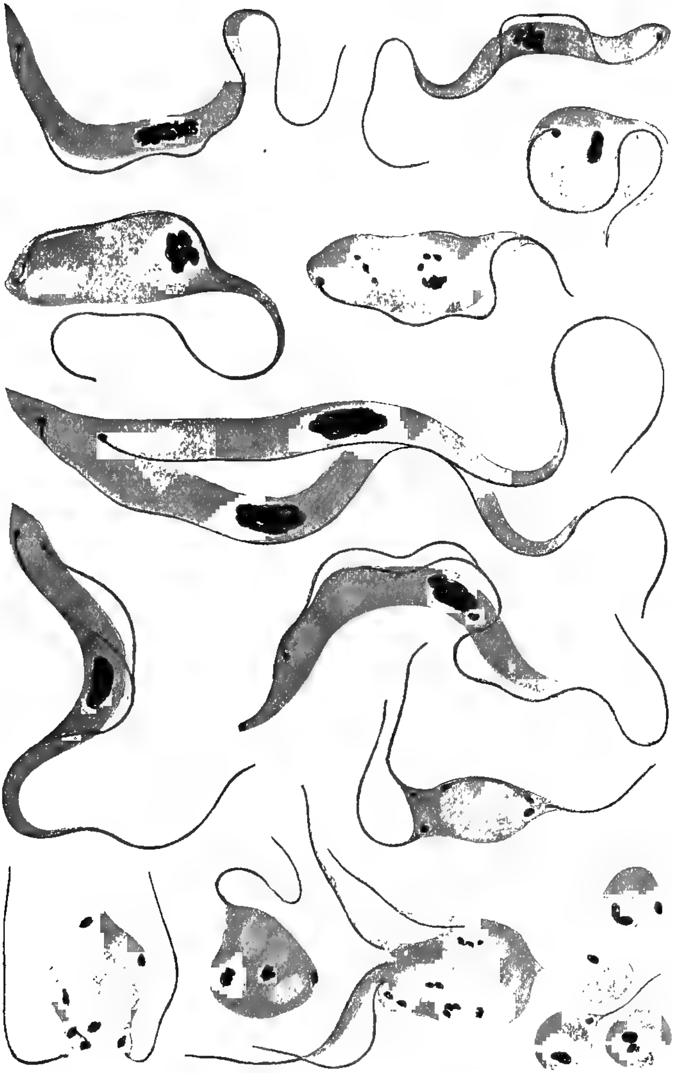


FIG. 84.—TRYPANOSOMA GAMBIENSE DUTTON.

(Forms found in the cerebro-spinal fluid.)

The figures in the top row show the ordinary forms; in the second row the stumpy forms; in the third and fourth rows longitudinal division. The lowest row shows multinucleate and polyflagellate forms (Rabinowitsch-Kempner forms), and small round flagellate and non-flagellate forms (Plimmer-Bradford and Castellani's forms). (From Castellani's report in Reports of the Royal Society on Sleeping Sickness.)

to nil, at which they remain for a period—the latent period—and then increase again in numbers and reappear in the peripheral blood.

Their investigations give the following results : The parasite may grow to a fair size, and then divide into two by simple fission, and this may be repeated till the blood is swarming with them. When this is the case a relatively thick band, said by Swellengrebel to be composed of melachromatic or volutine granules (axial filament), such as that described by Miss Robertson in *T. rajæ* and by Prowazek in *T. lewisi*, grows from the kinetonucleus down the endoplasm till it reaches or even passes the nucleus, or it may coil on itself, but eventually is connected with the trophonucleus.

The trypanosomes now decrease in numbers in the peripheral blood, and are found in the lungs, spleen, and bone-marrow. In these organs the protoplasm becomes detached from the periphery of the nucleus, which lies in a clear space. The nucleus contracts, and a large clear vesicle forms in connection with it, and around both a cytoplasmic sheath is formed. The rest of the cell body now disintegrates, and the flagellum with the kinetonucleus may be seen lying detached. These bodies now become lodged in the spleen and bone-marrow, where they remain intact for a period of ten days or more—through the whole of the negative or latent period when the trypanosomes are missing from the blood of the infected rat. Moore and Breinl, therefore, call them latent bodies. They consist of a flattened nucleus, containing a centrosome, and attached to a vesicle, the whole being surrounded by a ring of cytoplasm.

Just before the reappearance of the trypanosomes in the peripheral blood the centrosome inside the nucleus divides, and the new centrosome escaping from the nucleus becomes the kinetonucleus, and lies in the cytoplasm, which has now increased in amount. The vesicle has gradually disappeared. A new flagellum now appears, and gradually the latent body becomes a trypanosome. The rounded bodies with one or two nuclei, with or without the small flagella, are probably identical with the forms found by Castellani several years ago in the cerebro-spinal fluid of cases of sleeping sickness, and described by him under the term ‘ amœboid forms.’

Sexual Reproduction.—Apparently all observers are agreed that the parasite may show very diverse forms, and most of them consider that these forms may be classed into three types, especially when studied in the blood from the gut of the tsetse-fly.

Prowazek, Lühe, Nocht and Mayer consider them to be indifferent, male, and female forms. Minchin has carefully considered these forms, and finds that the ordinary or neutral form is that first met with in *G. palpalis*, and that it disappears, there being left only long, clear forms with an elongated nucleus and a long flagellum (male according to most observers) and a short thick form with a short flagellum (female). He sees very large forms appear, and then at the end of forty-eight hours they all disappear, and he can find no trace of them in the body of the Glossina. Koch, Gray, and Tulloch, described a fuller development, but the two latter had mistaken a parasite belonging to *G. palpalis*, and it is possible that Koch may have done the same ; but there is against this the fact that Koch was dealing with *G. fusca*, in which the trypanosome does not go through its life-cycle, and not *G. palpalis*.

Kleine's researches have already been mentioned on p. 252.

Trypanosoma cruzi Chagas 1909.

This trypanosome was discovered by Chagas in Brazil in the intestine of a conorhinus, and later in the blood of a child suffering from irregular fever, progressive anæmia, and enlargement of various groups of lymphatic glands. It is characterized by its large kinetonucleus, and by the facility with which it can be cultivated on blood agar.

According to Chagas, three different forms of the parasite can be seen in the blood :

1. Broad forms, with large round trophonucleus containing loose chromatin.
2. Slender forms with oval trophonucleus and dense chromatin.
3. Forms with a trophonucleus much larger than in the other two.

Chagas has succeeded in infecting domestic animals, such as cats and dogs, in the lungs of which he describes an intracorpuscular form of the trypanosome. It is spread by a bug—*Conorhinus sanguisuga*—belonging to the Reduviidæ. This bug bites at night, and from its habit of attacking the face is called by the natives barbeiro (barber). It bites not merely man, but domestic animals.

Chagas states that five to eight hours after the bug has been fed on an infected animal the trypanosomes in its alimentary canal lose their undulating membranes and their flagella, and then their kinetonuclei are found lying close to the trophonuclei. These forms multiply by division, but evidence in favour of conjugation and encystment has not been obtained.

Other Trypanosomes.—Among the numerous trypanosomes which have been described, the following may be briefly mentioned:

Trypanosoma ingeus Bruce, Hamerton and Mackie, 1909.

Found in the red buck and ox in Uganda ; large size (122 μ).

Trypanosoma nana Laveran 1905.

Balfour in 1904 discovered this parasite in cattle, on the White Nile, which appeared to be ill. The parasites are small, with no free flagellum, and are non-pathogenic for dogs, rabbits, and monkeys. Amœboid forms were found in the cerebro-spinal fluid.

Trypanosoma vivax Ziemann 1905.

An acute or chronic disease in cattle, sheep, and goats in the Cameroons was found by Ziemann to be due to a trypanosome which is distinguished from other pathogenic trypanosomes by its extraordinary activity. It is possibly spread by the Tabanidæ or *Stomoxys*, and the incubation period is five to eight days.

Trypanosoma pecaudi Laveran 1906.

In the French Sudan, in addition to mibori and souma, there is a thir unnamed disease—baleri, in Equidæ—caused by *T. pecaudi*, with two form like *T. dimorphon*—(1) long and slender, (2) short and broad.

Trypanosoma cazalboui Laveran 1906.

This trypanosome causes a disease in goats in French Guinea, spread b *Stomoxys bouffardi*, and, according to Bouffard, is identical with *T. vivax*.

A number of other forms have been described (*T. soudanese*, *T. congolense* in different diseases of animals in various parts of Africa and Asia, but it i probable that they are only slightly different from one or other and the above For details concerning these matters refer to 'Trypanosomes and Trypanosomiasis,' by Laveran and Mesnil; English translation brought up to date b Nabarro.

Trypanosoma criceti Lühe 1906.

Synonym.—*T. rabinowitschi* Brumpt 1906.

This trypanosome, which is very like *T. lewisi*, but distinguished by not being transferable to the rat, was found in the hamster (*Cricetus cricetus* L.) by Koch in 1881. A blood-sucking louse has not been found on the hamster, but *Pulex fasciatus* Bosc is common.

Trypanosoma cuniculi R. Blanchard 1906.

This trypanosome was found by Jobjet and Nabios in 1891 in the rabbit (*Lepus cuniculus* L.), in which it causes emaciation and perhaps diarrhœa. It is very similar to *T. lewisi*, but smaller. It will not infect white rats and guinea-pigs, but it can be cultivated. It is suspected that *Hæmatopinus ventricosus* Denny and *Pulex goniocephalus* Tasch may perhaps have something to do with its life-history.

Trypanosoma duttoni Thiroux 1905.

Dutton and Todd in 1903 saw a flagellate organism in the blood of mice obtained in a house in McCarthy Island on the Gambia River, but they considered it to be of the type of a *Herpetomonas*; but in 1905 Thiroux described a definite trypanosome in *Mus musculus* L. in Senegal which will only infect mice of all kinds—*e.g.*, *M. minutus* L. (the harvest-mouse)—and it is possible that Dutton and Todd saw one stage of its development.

A number of interesting researches have taken place with this trypanosome. Pricolo found that it could pass through the placenta and multiply in the fœtus, in which he describes latent forms very like those already mentioned in *T. lewisi*—*i.e.*, which resembled Leishmania—having only a rod-shaped kinetonucleus and trophonucleus.

Trypanosomes were found in fleas caught on infected animals, but they did not show any development.

Trypanosoma musculi Kendall 1906.

This parasite was found in 8 per cent. of the mice examined by Kendall in Panama. It was non-pathogenic, and resembled *T. lewisi*, but differed in not being capable of inoculation into rats.

Trypanosoma bandicotti Lingard 1904.

This trypanosome is probably not the same as *T. lewisi*, which it resembles in being pathogenic to guinea-pigs. It is found in *Nesokia bandicotti* Bechst in Bombay and the Deccan.

Trypanosoma indicum Lühe 1906.

T. indicum is found in the Indian squirrel (*Funambulus palmarum* L.) in Madras. It is very like *T. lewisi*, and only slight morphological differences can be found.

Trypanosoma blanchardi Brumpt 1905.

In *Myoxis glis*, the common dormouse. Like *T. lewisi*, but not inoculable into rats.

Trypanosoma myoxi R. Blanchard 1906.

Found by Galli-Valerio in *Muscardium* (*Myoxis*) *avellanarius* L., but nothing much is known about the parasite.

Trypanosoma pestanai Bettencourt and França 1905.

Found in *Meles taxus* Schreb, the badger, in Portugal. It is non-pathogenic.

Trypanosoma vespertilionis Battaglia 1905.

Synonym.—*Trypanosoma dionisi* Bettencourt and França 1908.

Dionisi found a trypanosome in the Italian bat (*Miniopterus schrenbersii*) in 1899, and since then numerous bats have been found to carry trypanosomes, and also they can be inoculated with the parasites of surra and mibori, which produce pathogenic effects.

T. vespertilionis has been found in bats from South Italy (Battaglia), Roman Campagna (Sambon), Brazil (Durham), India (Donovan), North Africa (Sergents), and from Portugal (Bettencourt and França). This parasite has been investigated by Battaglia, who has described a process of sporogony, and has shown that the blood filtered through a Kitasato filter is still infectious.

Trypanosoma nicolleorum Ed. and Et. Sergent 1905.

In the blood of *Vespertilio kuhli* Natt and *V. myotis* Bechst in Algeria; not transmissible to mice, rats, or rabbits.

The carrier of the infection is not known. Durham saw trypanosomes in *Stegomyia fasciata* which had fed on a bat, but they might have belonged to the mosquito. Fleas have been examined without success.

Trypanosoma minasense Chagas 1909.

This trypanosome was found by Carini and Chagas in Brazil in a marmoset, *Hapale penicillata*, and cultivated by Brumpt.

Trypanosoma elephantis Bruce, Hamerton and Mackie 1909.

Found in the elephant in Uganda; resembles *T. brucei*.

TRYPANOSOMES OF BIRDS.

In 1845 Gros found trypanosomes in the blood of goat-suckers and cranes, which are now known to be very common in birds; but the detection in blood-films is not easy, as the parasites are few and far between. According to Novy and McNeal, the cultivation method is much better.

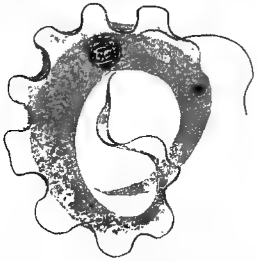


Fig. 85.—Trypanosoma vittatæ Robertson shows the Trypanosome rolling up prior to Division.

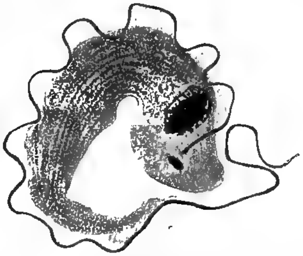


Fig. 86.—Trypanosoma leschenaultii Robertson.

(From drawings by Miss Robertson.)

Laveran and Mesnil summarize them into three types: (1) Trypanosomes of type *T. lewisi* in rats (*T. avium minus*); (2) trypanosomes of type of *T. rotatorium* of the frog; (3) long thin trypanosomes without free flagellum—distinct type.

A few examples may be mentioned:—*T. avium* Laveran 1903, in *Syrnium aluco* L., the wood-owl; *T. confusum* Lühe 1906, in *Agelaius phœniceus* L., and other North American birds; *T. laverani* Novy and McNeal 1905, in *Astragalinus tristis* L., North America; *T. paddæ* L. and Mesnil 1904, in *Padda oryzivora*, the Java sparrow.

TRYPANOSOMES OF REPTILES.

Tortoises.—*T. damoniæ* Laveran and Mesnil 1902, in *Damonia reevesi*, an Asiatic tortoise; *T. vittatæ* Robertson 1907 in *Emyda vittata* in Ceylon, the intermediate host being a leech.

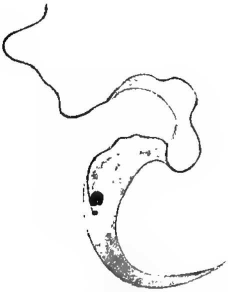


FIG. 87.—TRYPANOSOMA PERTENUE ROBERTSON.

(From a drawing by Miss Robertson.)

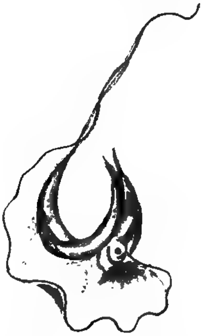


FIG. 88.—TRYPANOSOMA ROTATORUM.

(After Dutton and Todd.)

Lizards.—*T. boneti* Martin 1907, in *Mabuia raddonii*; *T. leschenaultii* Robertson 1907, in *Hemidactylus leschenaultii*, in Ceylon; *T. pertenue* Robertson 1907, in *Hemidactylus triedri leschenaulti*, in Ceylon.

Ophidia.—*T. pythonis* Robertson: Mesnil is doubtful whether this is not a hæmoproteus, while Sambon considers that it is a hæmogregarine (*H. robertsoni*).

TRYPANOSOMES OF FROGS.

The trypanosomes of frogs were discovered by Gruby as far back as 1842 in the form of the largest trypanosome known—*i.e.*, *T. rotatorium*.

It seems probable that leeches are the carriers of these parasites.

Trypanosoma rotatorium Mayer 1843.

Synonyms.—*Paramæcium loricatum seu costatum* Mayer 1843, *Amœba rotatoria* Mayer 1843, *Trypanosoma sanguinis* Gruby 1843, *Monas rotatoria* Lieberkühn 1870, *Undulina ranarum* Ray Lankester 1871, *Paramæcioides costatus* Grassi 1882.

This trypanosome is distinguished by its pleomorphism, having two main forms, with subdivisions:

1. *Flattened Forms.*—(*a*) Single flat form; (*b*) the folded form; (*c*) the plane spiral.
2. *Pectinated Forms.*—(*a*) Pectinated spiral; (*b*) the cornucopial form.

It is found in *Rana esculenta* L., *R. temporaria* L., *R. speciosum* in the Congo, *R. trinodis* in Gambia, *Hyla aborea* L.

Trypanosoma inopinatum Ed. and Et. Sergent 1904.

Found in *R. esculenta* L. in Algeria. It is very like *T. lewisi*, but is more stumpy. It is spread by the leech, *Helobdella algira*. It gives rise to herpetomonas forms, and Brumpt has been able to infect frogs by the bite of the infected leeches. It is also inoculable.

Trypanosoma nelspruitense Laveran 1904.

Discovered by Theiler in *R. angolensis* Bocage and in *R. theileri* Mocquart.

Trypanosoma somalense Brumpt 1906.

In *Bufo reticulatus* from Somaliland.

Trypanosoma sp. ?

Found by Tobey in the American newt, *Dienycleitus viridescens*.

TRYPANOSOMES OF FISH.

In 1841 the first known trypanosome was found by Valentin in the blood of *Salmo fario*, the brown trout.

Since that time a considerable number have been found in fresh- and salt-water fish all over the world. As examples may be mentioned *T. remaki* Laveran and Mesnil 1901, which exists in two varieties—*parva* and *magna*—and is found in pike; *T. rajæ* Laveran and Mesnil 1902 in *Raja punctata*, and is thought to be spread by a leech—*Pontobdella muricata; T. saccobranchi* Castellani and Willey 1905 in *Saccobranchus fossilis* in the Lake of Colombo, Ceylon.

Trypanosomes have been found in eels. Brumpt in 1906 described a number of new species in different kinds of fish, and recently Zupitza, in 1909, made a valuable addition to the knowledge of this subject.

TRYPANOSOMES OF INVERTEBRATA.

Trypanosomes belonging to the species and not due to the sucking of contaminated blood have been found in the tsetse-fly, in mosquitoes, in ticks, and in leeches.

In Tsetse-Flies.

Trypanosoma grayi Novy.—This parasite has either a long, wide, ribbon-like form, with a short, free flagellum and an undulating membrane, or a herpetomonas-like form. It is found in *Glossina palpalis*, and becomes encysted in the proctodæum, the flagellum disappearing into a pink-staining vacuole, while a pink-staining cap spreading from the hinder pole all round the parasite forms an irregular cyst, containing cytoplasm, a nucleus, and a kinetonucleus. It is possible that this form may escape with the fæces, and infect some unknown host by Minchin's contaminative type of infection.

Trypanosoma tullochi Minchin 1907.—This parasite closely resembles *T. gambiense*, from which it can be differentiated by the central round nucleus and the small centrosome. It is also found in *G. palpalis.*

In Mosquitoes.

T. culicis Novy 1907 is found in various Culicinæ. Novy strongly advocated the view that the trypanosomes found in mosquitoes which Schaudinn had fed on *Athene noctuæ* infected with halteridium should be defined as *T. noctuæ* Schaudinn 1904, a parasite of *Culex pipiens*, and the same for *T. ziemanni* Schaudinn 1904, also in *Culex pipiens;* and, further, that the trypanosome found by Durham in *Stegomyia fasciata*, which had been fed on bats, should be looked upon as belonging to the mosquito.

In Ticks.

T. christophersi Novy 1907, found in *Rhipicephalus sanguineus*, fed on dogs.

Remarks.—The presence of the Herpetomonas, Crithidia and Trypanosoma in blood-sucking animals may, therefore, be peculiar to those animals, or only acquired from their hosts. Hence it is quite possible for serious errors to arise in working out the life-history of these parasites, especially as infection of the blood-sucker may come from the eggs.

(2) TRYPANOPLASMA Laveran and Mesnil 1901. Emended 1904.

Trypanosomidæ living in the blood and alimentary canal of vertebrates with two flagella—one projecting anteriorly and the other running posteriorly, and raising the periplast into an undulating membrane. Kinetonucleus almost as large as the trophonucleus. Sporogony in the Hirundinea.

This genus, which was first described by Laveran and Mesnil, is interesting, first, because it shows definitely an anterior flagellum, which has disappeared in most trypanosomes, and a posterior flagellum, which, like all trypanosomes, carries the undulating membrane; secondly, because, according to Léger and Keysselitz, members of this genus are parasitic in the alimentary canal of fish, and not in the blood.

The body of a trypanoplasma is flattened, and often curved, with the concave side thicker than the convex, to which the undulating membrane is attached. The body is soft and of changing form.

At the junction of the anterior and middle thirds of the body can be seen two masses of chromatin. The one on the convex side is the trophonucleus, and the other on the concave side the elongated kinetonucleus, in front of which are two small chromatic granules, one of which gives rise to an anterior flagellum, which becomes free at once, and the other a posterior, which, turning backwards, runs the whole length of the cytoplasm, raising the periplast into an undulating membrane.

Division is longitudinal, the kinetonucleus dividing first, and then the flagella.

Often Trypanoplasmata show seasonable variation, the infection being more intense in hot weather. They are evidently pathogenic, producing anæmia associated with serous fluid in the peritoneum, pericardium, and œdema of the organs.

The parasite appears to be spread by leeches, in which the sexual forms conjugate by a fusion of nuclei, after reduction, and of the cytoplasm, from which results an oökinete possessing a trophonucleus and a kinetonucleus.

These oökinetes give rise to male, female, and indifferent forms of trypanosomes, which multiply abundantly. Parthenogenesis may occur.

Brumpt infected fish by the bite of leeches, but Keysselitz failed with *Pisciola geometra*, and it is hardly surprising, for he describes the leech as becoming ill, with swelling of the clitellar region, alteration in colour and activity, and finally death, thus showing that this leech could hardly be the usual definitive host. He has already noted the initial stages in *Hirudo medicinalis*. Another genus of leech which spreads these parasites is *Hemiclepsis*.

With regard to classification, Keysselitz is of the opinion that all so far described species should be considered to belong to one species—*Trypanoplasma borreli* L. and M.

Trypanoplasma borreli L. and M. 1901.

In the blood of *Leuciscus erythrophthalamus* (the rudd) and *Phoxinus lævis* (the minnow), and in the alimentary canal of the leech *Pisciola geometra*, and perhaps in *Hirudo medicinalis*.

Trypanoplasma cyprini Plehn 1903.

In *Cyprinus carpio*.

Trypanoplasma intestinalis Léger 1905.

This trypanoplasm is very important, because it was found in the œsophagus and anterior part of the stomach of *Box boöps*, a salt-water fish.

It is the first trypanosome described as existing outside the blood. In addition to typical forms, Léger describes globular parasites with three anterior flagella and a rudimentary undulating membrane, which reminds one of *Trichomonas*.

These he considers to be female forms, and says that he has seen conjugation with male forms.

Trypanoplasma ventriculi Keysselitz 1906.

This is found in the intestine of *Cyclopterus lumpus*, and is apparently a typical trypanoplasma.

Trypanoplasma varium Léger 1904.

In *Cobitis barbatula* (loach), and in *Hemiclepsis marginata*.

Trypanoplasma guernei Brumpt 1905.

In *Cottus globio*, and develops in *Pisciola*.

Trypanoplasma barbi Brumpt 1905.

In *Barbus fluviatilis*, and in the leech (*Pisciola*).

Trypanoplasma abramidis Brumpt 1905.

In the bream (*Abramis brama*) and the leech (*Hemiclepsis*).

Trypanoplasma truttæ Brumpt 1905.

In *Salmo fario*, and perhaps in *Pisciola*.

(3) TRYPANOPHIS Keysselitz 1904.

Trypanosomidæ in *Cœlenterata*, with two flagella, an anterior and a posterior. The kinetonucleus is situated anteriorly, and is much smaller than the trophonucleus.

Trypanophis grobbeni Poche 1903.

In the gastral cavity of different Siphonophora. The parasite is curved somewhat, like a trypanosome.

(4) ENDOTRYPANUM Mesnil and Brimont 1908.

The characters of this genus are intermediate between those of Trypanosoma and Hæmogregarina.

End. schaudinni Mesnil and Brimont 1908.

Found in a sloth; endoglobular, elongated (8 to 11 μ), terminating in a filament, with kinetonucleus and trophonucleus present.

FAMILY 4. HERPETOMONIDÆ.

Definition.—Encystina with a well-developed flagellum in some stage of the life-history, but with the undulating membrane either rudimentary or absent. The kinetonucleus is situate posterior to the trophonucleus, and remains in this position. Schizogony takes place by longitudinal division, but sporogony is as yet not fully known.

This family is very closely allied in some of its forms, especially Crithidia and Herpetomonas, to the Trypanosomidæ, for Miss Robertson, in her paper on a flagellate in the intestinal tract of

Pontobdella muricata, describes a parasite which in its earlier stages is like a Herpetomonas and a Crithidia, and then becomes a true trypanosome.

Patton has recently shown how closely allied the parasite of kala-azar is to a Crithidia, and the definite discovery of flagellated forms of Babesia indicate that it also is related to these genera.

There is also the genus *Achromaticus*, created by Dionisi for a parasite in the noctule: The genera are therefore:—(1) Herpetomonas; (2) Leptomonas; (3) Crithidia; (4) Leishmania; (5) Toxoplasma; (6) Babesia; (7) Achromaticus; possibly Histoplasma (p. 338) should also be included.

Herpetomonas Kent 1878.

Elongated, rod-like Herpetomonidæ with a single flagellum. The kinetonucleus is situated near the posterior end, so that the flagellum is not attached to the side of the body, but becomes free at once and projects posteriorly. There is no undulating membrane. The contractile vacuole is situate quite close to the posterior extremity.

The trophonucleus lies about the middle of the parasite, and possesses an achromatic substance with chromatic granules interspersed. The anterior end is tapering.

The species of Herpetomonas, though not parasitic in human beings, are important to the student of tropical medicine, as they are parasitic in insects. Thus, *Herptomonas muscæ-domesticæ* Burnett is parasitic in the intestinal canal of 8 per cent. of the house-flies (Prowazek); *Herpetomonas* (Crithidia) *minuta* Léger is parasitic in *Tabanus tergestinus*, and is intermediate between a true Herpetomonas with a long, tapering, posterior extremity, and a Crithidia with a round, thick, posterior extremity, and its kinetonucleus may lie near the trophonucleus.

There is considerable difference of opinion concerning the status of the Herpetomonidæ at the present moment. A number of observers, including Léger and Sambon, look upon them as merely stages in the life-history of trypanosomes; while others, such as Novy, McNeal, Ross, and Patton, hold that they are probably distinct from the blood trypanosomes. Woodcock, however, is probably correct when he says that those with trypaniform characters will probably be found to be stages in the life-cycle of trypanosomes, while the more typical herpetomonads will probably be found to be separate and distinct from these parasites.

In other words, the forms found in blood-sucking flies, leeches, etc., may be stages in the life-cycle of a trypanosome, and those found in non-blood-sucking flies, and perhaps those found in larvæ, may (though it is open to question in the larvæ of blood-suckers) belong to a truly separate genus. The life-history of these forms has been mainly studied by Prowazek and Patton, whose results differ remarkably.

Prowazek, in *H. muscæ-domesticæ*, describes asexual reproduction by longitudinal division, in which the trophonucleus divides first, then the kinetonucleus, and lastly the flagellum; while Patton fails to find the division of the flagellum, and states that the second flagellum is developed as an outgrowth from the kinetonucleus. Prowazek describes sexual conjugation, which Patton fails to find. Prowazek describes encystment, and considers that the infection is carried by the fæces, with which latter statement Patton agrees. Prowazek describes the male and female parasites penetrating into the eggs of the fly, and undergoing therein an autogamy by etheogenesis, in which the kinetonucleus carries out the development; by parthenogenesis, in which the trophonucleus is active; and by an indifferent type, in which both nuclei participate. There are, however, many transitional forms between these stages. Patton's description of the life-cycle is quite different, and resembles that which he has given for *Crithidia gerridis*. He further supports this life-cycle by his previous description of a herpetomonas in *Culex pipiens*.

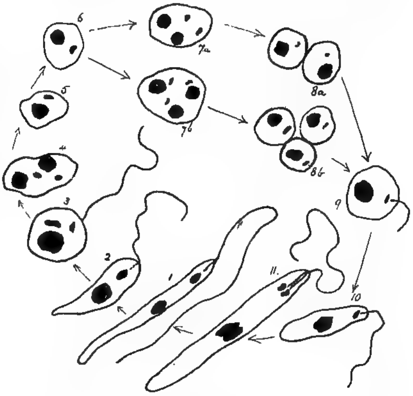


Fig. 89.—The Life-Cycle of Herpetomonas muscæ-domesticæ Burnett. (After Patton.)

1, Fully developed parasite; 2-5, stages of encystment; 6, encysted or preflagellate form; *7a-8a*, multiplication of the preflagellate form by simple division; *7b-8b*, multiple division; 9, young flagellate stage; 10, other form; 11, longitudinal division commencing.

Other Species.—*H. jaculum* Léger 1902, in the adults and larvæ of *Nepa cinerea*; *H. gracilis* Léger 1902, in the Malpighian tubules of the larvæ of *Tanypos*; *H. lesnei* Léger 1903, in the mid gut, near the Malpighian tubules, of *Dasyphora pratorum*; *H. subulata* Léger 1903, in the gut of *Tabanus glaucopis* and *Hæmatopota italica* Meig; *H. sarcophagæ* Prowazek 1904, in the gut of *Sarcophagus hæmorrhoidalis*; *H. bombycis* Levaditi 1905, etc.

Leptomonas Saville-Kent 1880.

Synonym.—*Phytomonas* Donovan 1909.

Herpetomonidæ, with a single long flagellum inserted far posteriorly, and without undulating membrane.

L. butschlii Saville-Kent 1880.

In *Trilobius gracilis*.

L. pyenosomæ Roubaud 1904.

In *Pyenosoma putorium* Wiedmann, in Africa.

L. davidi Lafont 1909.

In *Euphorbia pilulifera*, in Mauritius, Ceylon, and Réunion.

Crithidia Léger 1902.

Herpetomonidæ, in which the schizont is characterized by an attenuated posterior end, to which the flagellum is attached by a rudimentary undulating membrane. The kinetonucleus is situated close to the trophonucleus, but never anterior to it.

In 1902 Léger created this genus for a flagellate organism which he found in the alimentary canal of *Anopheles maculipennis,* and in 1908 Patton worked out the life-history of *C. gerridis.*

Crithidia gerridis Patton 1908.

This flagellate is a parasite in *Gerris fossarum Fabr* and in a species of Microvelia, and a water-bug allied to *Perillopus* found in Madras.

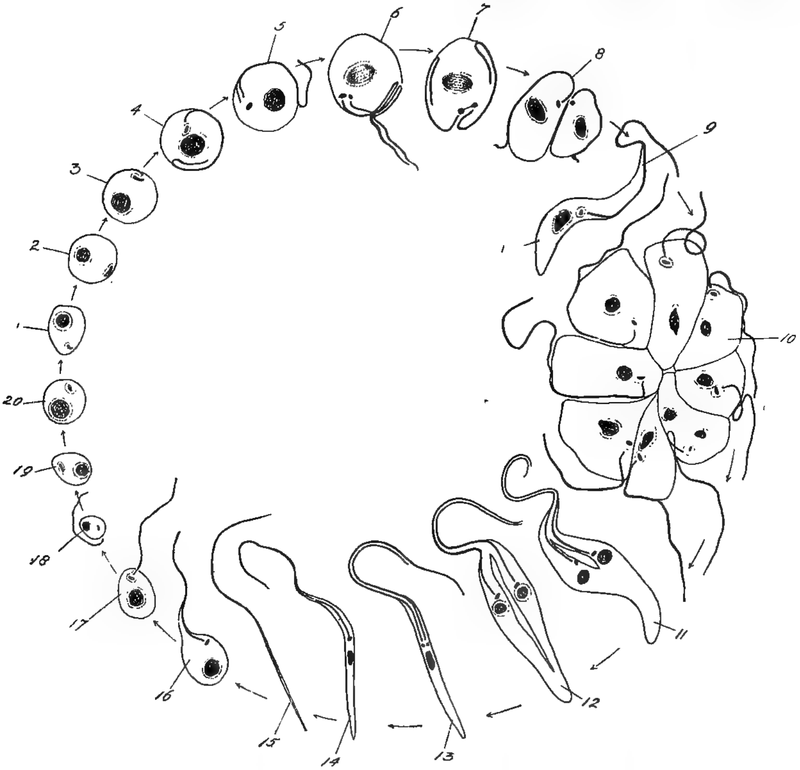


FIG. 90.—THE LIFE-CYCLE OF CRITHIDIA GERRIDIS PATTON.

(This is a diagram constructed from Captain Patton's drawings.)

14, Crithidial form; 15, very slender forms; 16-18, rounded forms losing their flagella; 19-3, preflagellate round forms, gradually increasing in size; 4, 5, formation of the flagellum; 6-8, division; 10, agglomeration; 11-13, division.

The flagellate is found in the crop of the insect as a round, oval, or pear-shaped body, 4 to 6 μ in length and 3 to 4 μ in breadth, in which lie a circular trophonucleus and a rod-shaped kinetonucleus.

The parasite grows and becomes vacuolated, showing, when coloured, a small pink staining area between the kinetonucleus and the periphery, which later becomes a distinct pink rod, and is a rudimentary flagellum attached by a rudimentary undulating membrane to the cell. This membrane shows as a faint pink band between the flagellum and the body of the parasite.

Later the flagellum can be seen arising from an achromatic area, the blepharoblast, close to the kinetonucleus, and running along the periphery of the parasite.

The kinetonucleus increases in size, and the trophonucleus shows its chromosomes, while chromatic particles appear in the cytoplasm.

The kinetonucleus now approaches the trophonucleus, and elongates and divides, while the flagellum thickens and splits longitudinally, so that there are two kinetonuclei and two flagella.

The trophonucleus and the cytoplasm now divide, so that two daughter cells are formed, which in turn divide, forming rosettes of eight to forty or more cells, measuring 6 to 10 μ in length by 4 to 8 μ in breadth.

Eventually the rosettes break up, and the rounded parasite has a central nucleus and a kinetonucleus at one side, and from a point close to this a flagellum passes round its circumference, giving it an undulating contour. The parasite elongates, and the posterior end is drawn out along the flagellum; the length is now 15 to 45 μ and the breadth 2 to 4 μ. They are often found agglomerated together.

Longitudinal division now takes place rapidly, and the parasites pass down the intestinal tract and shorten, until they become round bodies with long flagella. A change then takes place, the flagellum becoming absorbed and finally detached, and the parasite appearing as a rounded body with a tropho- and a kinetonucleus. The life-history is completed by the bodies being discharged with the fæces into the water, and so taken up by a new host. The ovaries and eggs were not infected. This is an excellent example of Minchin's contaminative method of infection.

Crithidia melophagia Flu 1908.

Flu has described *Crithidia melophagia* in *Melophagus ovinus*, a parasite of the sheep. He gives an account of asexual and sexual reproduction. The latter is characterized by a process of reduction, followed by conjugation with the formation of an oökinete and the infection of the eggs of the insect, which may cause a second generation of flies to carry the organism (Fig. 75).

Other Species.—*C. fasciculata* Léger 1902, in the intestines of females of the species *Anopheles maculipennis* and in *Culex fatigans* Wied.; *C. campanulata* Léger 1903, in the intestine of *Chironomus plumosus*; *C. minuta* Léger 1903: this parasite is found in *Tabanus tergestinus*, and is characterized by having a thick rounded end.

Leishmania Ross 1903.

Synonyms.—*Piroplasma* Laveran and Mesnil 1903, *Helcosoma* Wright 1903, *Herpetomonas* Rogers 1904.

Definition.—Herpetomonidæ, living principally in endothelial cells, but also found in leucocytes and in the peripheral blood of mammals as small, oval, cytoplasmic masses with tropho- and kinetonuclei, and developing into flagellate bodies in cultures.

Three species are known in man, morphologically similar, but pathogenetically different: *Leishmania donovani* Ross 1903, *L. tropica* Wright 1903, and *L. infantum* Nicolle 1908.

Leishmania donovani Laveran and Mesnil 1903.

In 1900, when examining a film taken post mortem from a case of Dum Dum (a place near Calcutta) fever, Colonel Sir William Leishman saw a large number of small oval bodies, each of which contained a large and a small chromatin mass.

It was not until May, 1903, that he published an account of these parasites, suggesting that they might be trypanosomes, and might possibly be the cause of similar anomalous cases of so-called malarial fever.

In July, 1903, Major Donovan reported that he found bodies similar to those described by Colonel Leishman in blood taken from cases during life by splenic puncture.

In July, 1904, Rogers announced that he had succeeded in observing the development of these parasites into flagellates, by cultivating the blood taken from the spleen of a case of kala-azar, in sterile citrate of sodium solution incubated at 22° C. Christophers, in 1904, considerably added to our knowledge of these parasites, and Patton, in 1906 and 1907, showed that they were not merely found more commonly in the leucocytes of the peripheral blood than had been previously believed, but that they could develop into typical flagellates in the bed-bug, *Cimex rotundatus* Signoret 1852 (which is the same as *C. macrocephalus* Fieb).

The present state of the knowledge with regard to this parasite is that it is generally believed to be the cause of the disease called tropical splenomegaly, or kala-azar; and that it is probably spread by means of some insect; the particular carrier is not known.

Geographical.—The parasite is known to occur in India, Ceylon, China, Arabia, Egypt, and the Sudan, and many parts of Africa.

The Parasite.—The parasite is round, oval, or pyriform in shape, measuring 2 to 3·5 μ in length by 1·5 to 2 μ in breadth, with a granular cytoplasm containing two chromatic masses: the larger, more rounded, stains slightly; the smaller, rod-shaped, stains deeply. From the latter a linear structure (Novy and Mesnil's rhizoplast) runs to the acute end. A vacuole is also often present.

Distribution in the Body.—The parasites are found sometimes in large numbers in endothelial cells in the capillaries of the liver, spleen, bone-marrow, lymphatic glands, and mucosa of the intestine, in the blood from the femoral, portal, and hepatic veins, and more rarely in the circulating blood shortly before death.

Parasites liberated from the large cells are apparently taken up by mononuclear, polynuclear, and rarely eosinophile leucocytes, and may be occasionally seen in films obtained from the finger even in early stages of the disease, though more frequently near the end.

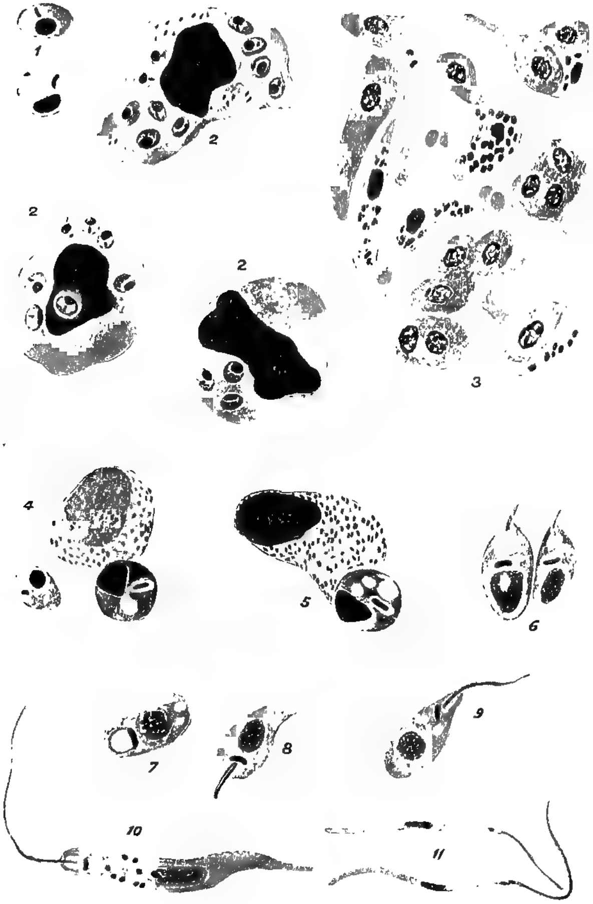


FIG. 91.—LEISHMANIA DONOVANI LAVERAN AND MESNIL.

1, Free binucleate forms (after Christophers); 2, endothelial cell and leucocytes containing parasites (after Christophers); 3, capillary in the liver, showing endothelial cells containing parasites (after Christophers); 4, two parasites escaping from a leucocyte in the alimentary canal of the bug (after Patton); 5, further development in the bug (after Patton); 6, Flagellate forms in the bug (after Patton); 7-11, culture forms (after Leishman); 7, 8, 9 show the development of the flagellum.

Treutlein has stated that the parasite is to be also found in red blood cells.

Schizogony.—Multiplication in man takes place by simple binary fission and by multiple division into three or more bodies. Division begins at the broad end, but cytological details are still wanting.

Development in the Bug.—According to Patton the parasites are ingested by the bug enclosed in the large cells or leucocytes as just mentioned, and develop into fully flagellated forms without reference to the temperature of the external air.

The first change begins usually by an increase in size up to 4 to 7 μ and a vacuolation of the cytoplasm on the second day, but may be deferred for several days.

The single parasite may proceed directly to flagellation by the appearance of an area stained bright pink by Giemsa, and called 'the flagellar vacuole.' This vacuole, which has a dark centre, rapidly increases in size up to 1 to 3 μ, and, passing to the surface, sends out a small pink brush, which forms the flagellum by merely growing longer. There appears to be no doubt that the flagellum forms in this vacuole, and is not directly connected with the kineto-nucleus.

The flagellate form has a dark blue, granular cytoplasm with a circular trophonucleus, which stains deeply in the centre, and a kinetonucleus lying across the long diameter, and situated near the trophonucleus, and possessing a long flagellum consisting of a number of filaments adhering closely together, inserted into a pale area near the kinetonucleus.

These parasites may divide into two equal or unequal flagellate forms, and apparently may go on so dividing for a length of time.

Instead of proceeding directly to flagellation, the parasite may show a division of its nuclei into two, with the formation of two flagella, and then division into two flagellate parasites, or the nuclei may multiply without division of the cytoplasm, so that forms containing four to eight nuclei may be found together, which eventually break up into separate flagellate forms.

Leishmania tropica Wright 1903.

Synonyms.—*Helcosoma tropicum* Wright 1903; *Crithidia Cunninghami* Carter 1909.

This parasite was described by Wright as being found in cases of Oriental sore, and later Martinowski and Bognoff found the same parasites in Bouton d'Alep. It is believed by some that this parasite was first described by Cunningham in 1885, and more completely studied by Firth, who called it *Sporozoon furunculosum* Firth 1891; if this is so, the correct name of the parasite should be *L. furunculosa* Firth 1891.

It was specially investigated in 1905 by James in Delhi sore, Lahore sore, and Frontier sore. Nicolle has obtained cultures of the parasite on the McNeal-Novy medium, and Carter describes sexual forms. It differs in no morphological respect from *L. donovani*, but only produces a local sore. Carter, Balfour, and Nattan-Larrier believe, in our opinion correctly, that there are several varieties or species included under the term *L. tropica*.

Leishmania Infantum Nicolle 1908.

Pianese, and later Nicolle, have found parasites resembling *L. donovani* in cases of febrile splenic anæmia in children in Italy and North Africa. Both consider it to be a different species from *L. donovani*, and Nicolle has given it the name of *L. infantum*, and has cultivated it on blood agar, on which it assumes the appearance of a herpetomonas.

He has succeeded in reproducing the disease in monkeys, and less typically in dogs, which are also found naturally infected, and, in his opinion, may be the natural reservoir of the parasite.

Leishmania farciminosa Rivolta 1873.

Oval or roundish bodies, with double contoured membrane and one or two chromatic masses, found in the leucocytes of horses suffering from lymphangitis by Rivolta, and thought to be a *Cryptococcus*, but now considered by Galli-Valerio to be a *Leishmania*, though Gasperini, probably correctly, considers them to constitute a new genus, *Lymphosporidium farciminosum* Rivolta.

Toxoplasma Nicolle and Manceaux 1908.

Definition.—Parasites resembling Leishmania, but possessing only one central chromatic mass. In shape, crescentic, oval, or reniform. Reproduction by longitudinal division. Found in mononuclear and polymorphonuclear cells in the spleen and other organs. Attempts at cultivation have so far failed.

Toxoplasma gondii Nicolle and Manceaux 1908.

Endoleucocytic crescentic parasites 6 to 7 μ by 3 to 4 μ, found in the spleen and other organs of *Ctenodactylus gondii.*

Toxoplasma cuniculi Splendore 1909.

Found by Splendore in the spleen and other organs of the rabbit, in which it produces lesions resembling kala-azar. Shape, oval or reniform; length, 5 to 8 μ; breadth, 2·5 to 4 μ.

Babesia Starcovici 1893.

Synonyms.—*Hæmatococcus* Babes 1888 (*non* Agardh), *Pyrosoma* Smith and Kilborne 1893 (*non* Péron), *Ixodioplasma* Schmidt 1904, *Apiosoma* Von Wandollek 1875 (*non* Blanchard 1855), *Piroplasma* Patton 1895, *Amœbosporidium* Bonome 1895.

Herpetomonidæ with a flagellate stage, which is at present but little known. Schizogony takes place in the red corpuscles by a process of gemmation, giving rise to rounded or pyriform merozoites. Sporogony is not well known, but takes place in ticks. The life-cycle can hardly yet be said to be thoroughly understood, for, as Breinl and Hindle and Miyajima have shown, there is a flagellate stage, and any complete life-cycle should apparently contain some such stage. This flagellate stage is of importance in indicating that the Babesia belong to the Binucleata, and are related to the Trypanosomidæ and Herpetomonidæ.

The best-studied species is *Babesia canis*, whose life-history will be described.

Babesia canis Piana and Galli Valerio 1895.

Synonym.—*Piroplasma canis* P. and G. V. 1895.

In 1895 Piana and Galli Valerio found a characteristic hæmatozoön in the red blood-corpuscles of a dog which was infested by ticks (*Ixodes reduvius* L.), and which was suffering from fever, weakness, and slight jaundice, after having hunted in marshy localities. This hæmatozoön occupied 3 to 4 per cent. of the corpuscles, and also occurred free in the plasma. In the corpuscles the parasite appeared as pyriform bodies, as many as two, three, four, or five in one corpuscle, and showed amœboid movement. The dog in question recovered, but in other dogs the post-mortem showed fluid blood, congested liver and spleen, with icteric staining of the tissues and necrotic foci in the omentum near the pancreas. Other symptoms noted by them in dogs were hæmoglobinuria, anorexia, prostration, and emaciation.

In 1899 Hutcheon described the disease caused by this parasite as 'malignant jaundice' or 'bilious fever' in dogs. It is also known as 'malignant malaria,' 'hondziekté,' and 'malarial fever,' and is said to have often been mistaken for distemper. The disease is by no means uncommon in dogs in the tropics, and should be called 'canine babesiasis.'

Geography.—It is known in Europe, especially in Lombardy and other parts of Italy; also in France. In Africa it is found in South Africa, East Africa, Senegal, and other parts of West Africa, and also in North Africa, including Egypt. Nuttall suggests, however, that the African *Babesia* may be different from the European. In Asia it is found in India and Ceylon.

Place and Season.—It appears to be more common in coast towns and districts, and less common in higher inland places. It appears to have a seasonal variation, but this is not properly understood.

The Parasite.—The life-cycle in the dog has been most carefully studied by Nuttall and Graham-Smith.

In the fresh blood it is noted that the infected corpuscles are pale and enlarged, and contain irregular, dark-coloured, pear-shaped bodies, possessing a central refractive portion. Amœboid or globular non-motile bodies may be noted, and also many free forms.

In specimens stained by Leishman's method the parasites seem to consist of a blue-coloured cytoplasm, with a delicate vacuolated or trabecular structure centrally, but more condensed around the periphery. This cytoplasm may contain a single homogeneous nucleus, which has a vivid red colour, and is often connected by a thin strand with a loose mass of chromatin, which is situated near the blunt end. The parasite contains a vacuole.

Schizogony.—A free pyriform parasite (pyriform stage) enters a normal red blood-corpuscle and becomes rounded (ring stage) in shape, while the loose mass of chromatin is drawn near to the original nucleus, where it condenses. Finally it fuses with that nucleus, forming a single chromatin mass.

The parasite now throws out pseudopodia and appears as an amœba (amœboid stage), and the chromatin subdivides into two unequal masses, connected with a thin strand.

This amœboid stage lasts for a long time, at the end of which the parasite enters upon a quiescent stage, in which the vacuole appears in a subcentral position, and the chromatin, which lies along its margin, has its two masses widely separated, though still connected by the thin strand already referred to. The smaller mass has divided into two, making in all three masses of chromatin connected together by chromatin strands.

Two small symmetrical processes of cytoplasm protrude from the parasite in the neighbourhood of the two small chromatin masses, which they carry with them.

The processes enlarge at the expense of the rest of the cytoplasm, and the vacuole divides, and the so-called trefoil stage is reached, in which the main mass of the chromatin, much reduced in size, lies at the base of the two processes.

The single strand connecting the two smaller chromatin particles has shortened and disappeared, so that the strand of each small mass now rises directly from the principal chromatin mass. This now divides into two nuclei, connected by a strand, while the cytoplasmic processes become large. Finally, the cytoplasm divides, and two pyriform parasites are found lying side by side in one corpuscle, an arrangement considered typical of a babesia.

In each parasite is a vacuole, and a principal chromatic nucleus situated near the pointed extremity, from which a tail of loose chromatin runs alongside the vacuole towards the blunt extremity.

The corpuscle now ruptures and liberates the two parasites and some granules, representing residual matter, from the parasite or the corpuscle, or both.

Two slight variations of the process have been described by Nuttall and Graham-Smith: in one the two nuclei and their strands form an hourglass-shaped mass, and in the other the strand and second nucleus form a reticular mass; but both develop into the stage depicted in the diagram. Four pyriform parasites may be found in a corpuscle instead of two, and this may come about by an invasion of the corpuscle by two pyriform shapes, which proceed to division, or by the division of the uninuclear shape into two, both of which proceed to develop regularly. Reproduction by gemmation with the formation of one or two buds has been described by Breinl and Hindle, and of many buds by Kinoshita.

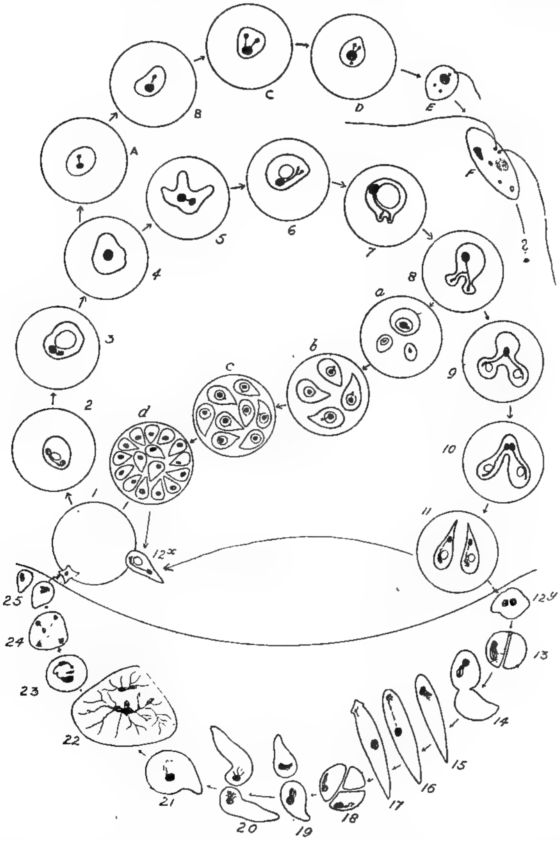


FIG. 92.—DIAGRAM OF THE LIFE-CYCLES OF BABESIA CANIS.

(After Nuttall and Graham-Smith, Christophers, and Breinl and Kinghorn.)

1-12*x*, Reproduction by simple division; *a-a*, reproduction by multiple division; A-F, development of a flagellate form; 12*y*-25, sporogony in the tick.

Flagellate Forms.—Nuttall and Graham-Smith in 1905 described large forms in the blood of the first dog which they infected in Cambridge by ticks from South Africa. These forms were found on the fourth, fifth, and tenth days, and occurred in the peripheral blood and in that from a kidney. They were sausage-shaped, with rounded or tapering extremities. In some the chromatin was almost entirely concentrated in the middle, while in others it appeared to be of loose texture. Kinoshita has seen similar parasites in blood from the heart, the pancreas, and the lungs after death. The significance of these parasites is not yet understood.

Free parasites with flagella-like processes have been seen by Pound, Bowhill, Le Doux, Nuttall and Graham-Smith, Kinoshita, Fülleborn, and Breinl and Hindle, the last-mentioned observers describing the development of large biflagellate forms from the normal intracellular parasite.

The significance of these forms is not understood, Breinl and Hindle considering that they are such very transient stages in the life-history that they may easily be overlooked.

The development as given by Breinl and Hindle is associated with a binucleated form.

Cultivation.—Kleine, Nuttall, and Graham-Smith have attempted to cultivate *Babesia canis* in defibrinated blood. Kleine has observed elongated forms with radiating processes, similar to those found by Koch in ticks.

Nuttall and Graham-Smith have observed the same forms, but consider them to be intracellular, the hæmoglobin having nearly disappeared from the red cells.

Inoculation.—It was first shown by Dr. Corrington Purvis in 1900 that the disease could be spread from dog to dog by blood inoculation.

Infection from Tick-Bites.—Piana and Galli Valerio, when they discovered the parasite in 1895 in Italy, suspected that it was transmitted by the tick *Ixodes reduvius* L., but the first actual demonstration that this really took place was by Loundsbury in 1901, by the bites of the tick *Hæmophysalis leachi* Audouin, in South Africa.

Dermacentor reticulatus Fabr is suspected as the spreader of the disease in France.

This subject has been carefully investigated by Loundsbury, who finds that the parent tick, having gorged with blood, falls to the ground and lays her eggs, which develop into six-legged larvæ.

These larvæ do not infect the dog, which they attack as soon as possible, and on whom they remain two days sucking blood. After dropping off, they in due time shed their larval skin, and become eight-legged nymphs, which again bite the dog, but do not infect it.

The nymph, after dropping off, undergoes metamorphosis, and sheds its nymphal skin and becomes the sexually mature tick, which is the only form that spreads the infection, a fact confirmed by Nuttall.

Christophers has traced out the development in *Rhipicephalus sanguineus* Latreille, thus finally confirming the idea of the transmission through the tick.

Development in the Tick.—When an adult tick or a nymph bites a dog and takes in blood containing the oval parasites already described, these parasites develop in the gut into round or oval bodies, 4 to 5 μ in diameter, the chromatin remaining undisturbed.

The cytoplasm now partially divides into a portion with and a portion without chromatin, the latter turning round to form a tail to the former, thus constituting a club-shaped body, which gradually becomes an oökinete.

In the adult these wander into the ova, while in the nymph they simply pass into the embryonic tissue.

In either case they become rounded, and form the zygote, which breaks up into sporoblasts, and these, again, into sporozoites, which infect the salivary glands of the nymph and the adult of the second generation. This development explains Loundsbury's experiments.

Pathogenesis.—The pathological effects are divided by Nocard and Leclainche into two types—the acute, always fatal, and the subacute, ending in recovery.

Acute Form.—In the severe attack the dog quickly becomes ill with high fever (40° C.), accompanied with great weakness. After the attack of fever comes a stage of subnormal temperatures. The mucous membrane becomes pallid, bluish, or icteric. Respiration is laboured, and the movements of the animal are shaky. Vomiting is frequent. The spleen is enlarged, the urine albuminous, and in 3·5 per cent. of cases there is hæmoglobinuria. The blood is pale and watery, and the serum stained with hæmoglobin or bile pigments; the red corpuscles are reduced (in one dog, according to Wright, from 5,800,000 to 1,000,000) and altered, some becoming larger, others smaller, than normal, and often nucleated. The hæmoglobin is diminished, the smallest amount observed being 17 per cent. Usually the leucocytes are increased up to even 60,000, but in some cases they are reduced. Polymorphonuclear and mononuclear leucocytes share the general increase. Phagocytosis is not energetic, being rarely met with. The animal dies in from three to six days.

Subacute Form.—This is characterized by progressive anæmia and feebleness, with sometimes a little hæmoglobinuria or a little icterus. Fever may at first be high, but generally falls to normal. The anæmia is very pronounced, and is accompanied with paralysis, etc.

The attack lasts six weeks, and the convalescence takes three months.

Post-Mortem Appearances.—The mucous membranes are pale, and there is icteric staining of the tissues. Congestion and enlargement of the spleen, more rarely of the liver, œdema of the lungs, congestion of the kidneys, and inflammation of the stomach and intestines may be noted, but sometimes no macroscopical lesions are to be seen.

Histological.—The capillaries of the alveoli are dilated, and their walls show some proliferation of the cells, and there may be leucocytes and red corpuscles in the lumen of the air cell.

In the heart the capillaries are dilated, and there may be slight hæmorrhages. There is no change in the skeletal muscles. The liver has the central vein and the interlobular capillaries much dilated, as are the intralobular vessels. The fibrous tissue is normal, but the liver cells are distorted, and in many cases destroyed. The spleen contains a large quantity of blood in its pulp. The kidneys only show dilatation of the bloodvessels, especially those of the glomeruli. The suprarenal capsules have all the capillaries (cortex and medulla) dilated, as has the pancreas. In the brain and spinal cord there is only slight dilatation of the capillaries, and slight excess of cerebrospinal fluid. In the small intestine the vessels of the villi are congested and crowded with infected corpuscles, as are those of the mesentery and omentum. The lymphatic glands are normal, except dilatation of their smaller vessels. The general histological condition is engorgement of the organs by dilatation of the capillaries.

Treatment.—Quinine, benzoate of soda, calomel, etc., have all been advised. Nuttall and Hadwen have introduced Trypanbleu treatment with success.

Babesia bigemina Smith and Kilborne 1893.

Synonyms.—*Pyrosoma bigeminum* Smith and Kilborne 1893; *Apiosoma bigeminum* Wandollek; *Piroplasma bigeminum* Patton; *Babesia bovis* Chauvelot; *Ixodioplasma specificum bovum* Schmidt.

Babesia bigemina is the cause of Texas fever in oxen, and appears as pyriform, round, or amœboid cells, and also as flagellate forms. It can be cultivated on artificial media.

Koch has traced the development in the tick, in whose gut the parasites leave the red cell and become long and club-shaped, at the broad end of which is found a round chromatin mass. From the club pseudopodia project.

This club then becomes spherical, and immense numbers of amœba-like forms appear, which are said to grow into clubs.

Pathogenesis.—The disease may exist in two forms, a grave and a benign.

The usual symptoms of high fever, hæmoglobinuria, icterus, anæmia, paralysis, constipation, and death in a week or less, are exhibited in the grave form, in which the mortality is 60 to 80 per cent.

In the benign form there is anæmia without hæmoglobinuria as a rule, and the duration is about fourteen days.

The disease can be spread by inoculation or naturally by the bites of infected ticks—*Margaropus australis* Fuller in South America, Cuba, Porto Rico, Australia, and the Philippines, and by *M. decoloratus* Koch in South Africa.

Post Mortem.—The usual post-mortem signs are visible.

Treatment.—There is no specific treatment. Krägerud advises intravenous injections of 1 in 100 of protargol or formol, and afterwards a beverage of 10 grammes of lysol and carbolic acid in 500 grammes of distilled water. Lignières recommends chloride of sodium and purgatives. Quinine has also been advised. Nuttall and Hadwen's treatment should be tried.

Babesia parva Theiler.

Synonym.—*Piroplasma theileri.*

This is the cause of East Coast fever in cattle in Rhodesia, and is also found in India and Japan.

Parasite.—The parasite appears in the blood as minute bacillary forms (called *Theileria* by some writers), or as small rings, which later become larger and give the typical pyriform appearance, being frequently arranged in the form of a cross. Very large forms, consisting of protoplasmic masses containing numerous chromatin particles, may be found in the endothelial cells of the spleen and lymphatic glands. It is spread by *Eurhipicephalus appendiculatus* Neum and *Eusimus* Koch. It is transmitted by the nymphs and the adults. Development has only been traced up to round forms. Miyajima states that he has cultivated the parasite in broth, producing trypanosome-like bodies, but this has not been confirmed.

Incubation.—Fourteen days.

Symptoms.—The symptoms produced are very similar to those caused by *B. bigemina*, but there is very little anæmia and no hæmoglobinuria.

Mortality.—The mortality is about 90 per cent.

Post Mortem.—The autopsy shows œdema of the lungs, inflammation of the lymphatic glands, and infarcts in the lungs, liver, and kidneys.

Babesia bovis Babes 1888.

Synonyms.—*Piroplasma annulatum* Dschunkowsky and Luhs 1888, *Piroplasma bigeminum* Babès, *Hæmatococcus bovis* Babés.

Babesia bovis is the cause of red water or hæmoglobinuric fever in European cattle and in red deer (*Cervus elaphus* L.), and is spread by the tick *Ixodes reduvius* L. and *Margaropus annulatus* Say.

The disease produced may be acute or chronic. In the acute form about 90 per cent. of the red cells are infected by bacillary or ring-like parasites, which cause high fever, quick pulse and respirations, seldom hæmoglobinuria, with convulsions and death in one or two weeks; or a chronic form, with minute coccus-like parasites in 10 to 40 per cent. of the red cells, producing weakness, jaundice, and anæmia. The post-mortem shows hæmorrhages into many organs.

Babesia mutans Theiler 1907.

Synonym.—*Piroplasma mutans* Theiler 1907.

This babesia is found along with *B. bigemina*, in cattle in the Transvaal, and produces forms like *B. parva*, but distinguished by being inoculable. It is not known how it is spread.

Babesia ovis Babes 1880.

Synonyms.—*Hæmatococcus ovis* Babes, *Piroplasma ovis* Laveran, *Amœbosporidium polyphagum* Bonome.

Babesia ovis is found in sheep in Europe, Africa, and the West Indies, as large intracorpuscular and extracorpuscular forms, and causes anæmia, hæmoglobinuria, hæmaturia, and bile in the urine, and also blood in the motions. The mortality is 50 per cent.

The post-mortem shows œdema of the tissues, enlargement of the spleen, inflammation of the liver, kidney, and bowels, in the last of which there may be ulcers.

The *Babesia* is spread by the daughter adult tick developed from the *Eurhipicephalus bursa*, which sucked the infected blood. It is inoculable into other sheep.

Babesia equi Laveran 1899.

Synonym.—*Piroplasma equi* Laveran 1899.

Babesia equi is the parasite of babesiasis in horses, mules, donkeys, and zebras in Africa, Germany, Italy, and Venezuela.

The disease appears to have been first differentiated by Wiltshire, in 1883, as anthrax fever, which name was changed to biliary fever by Hutcheon. The parasite was first seen by Guglielmi, in Italy, in 1899.

It differs from *Babesia canis* in existing in large and small spherical forms, in large and small pyriform shapes, in large and small rod-like bodies, in rosettes of four, and sometimes as free flagellate forms. Koch believes that this list includes two different types of parasite—one of parasites arranged in groups of four, and the other like *B. canis*.

It is very difficult to inoculate, and is believed to be spread by the blue tick (*Rhipicephalus decoloratus*).

The incubation period is not known. The disease begins with high fever, but becomes subnormal before death. The appetite varies. The animal is very weak, and in the later stages becomes paralytic and comatose. Anæmia and jaundice are noted. The pulse varies, being often weak and irregular. The respirations are accelerated. Bowels often constipated ; urine is highly coloured, and hæmoglobinuria may occur. The disease may be acute or chronic.

In acute cases death may take place in from two to five days, but the mortality is not high. Secondary and terminal infections may take place.

The post-mortem reveals emaciation and icteric staining, and anæmia of the tissues, enormous enlargement of the spleen, and thin, watery blood. The liver is yellow and congested ; the kidneys are enlarged and anæmic ; the lymphatic glands are hæmorrhagic, as may be the mucosa of the intestines. The heart is sometimes enlarged. The lungs are usually normal.

Babesia pitheci P. H. Ross 1905.

Synonym.—*Piroplasma pitheci* P. H. Ross 1905.

This organism caused babesiasis in a species of *Cercopithecus* from Kikuga, in Uganda.

The parasite is a non-pigmented, pear-shaped, oval, or round endocorpuscular body, being 1·5 μ in diameter when round, and 3 by 2 μ to 2·5 by 1·5 μ in the pyriform shapes. It may be single, double, or in multiples of two, four, eight, or sixteen.

Nuttall and Graham-Smith have investigated the parasite carefully, and conclude that it is a true babesia, and multiplies in the same manner as *B. canis* ; and they figure one body in a corpuscle very like the peculiar free forms noted in *B. canis*.

Ross tried inoculation into dogs twice, but though one of the dogs showed a temporary rise of temperature, the experiment failed. No ticks were found on the monkeys, or in the box in which they lived. The disease causes fever, and killed four out of twelve monkeys.

Babesia muris Fantham 1906.

Babesia muris causes a chronic disease in mice, in which it exists as pyriform intracorpuscular parasites, singly and in pairs (as many as four and six have been seen). The secondary mass of chromatin has not been observed, and no typical dividing forms have yet been seen.

Babesia cervi França and Borges 1907.

This *Babesia* is found as bacillary and cross forms in the blood of *Cervus dama* L. Its development is not known.

Babesia aristotelis Denier 1907.

This parasite is found in *Cervus aristotelis* in Annam.

Babesia cellii Castellani and Chalmers 1908.

This parasite is found in *Macacus pileatus* in Ceylon, in bacillary and pear-shaped forms, lying side by side in the same erythrocyte. The development has not been traced.

Babesia herpetedis França 1908.

B. herpetedis is found in considerable numbers in *Herpestes ichneumon* L.. the mongoose, as small spheres, with the chromatin arranged as a cross, or as pyriform shapes, or in fours arranged in cross form.

Babesia quadrigemium (Incertæ Sedis) Nicolle 1907.

This parasite is found in *Ctenodactylus gundi* in North Africa, and Nuttall and Graham-Smith point out that its method of division and its chromatin are so peculiar that its position is doubtful.

Babesia hominis (Doubtful) Manson 1903.

Wilson and Chowning in 1902 described ovoid intracorpuscular bodies with amœboid movements in cases of spotted fever of the Rocky Mountains. Some parasites are distinctly pyriform, and may be in pairs, which are united together by a fine thread.

Wilson and Chowning further came to the conclusion that the disease was spread by a tick, *Dermacentor reticulatus*.

In these findings they were supported by Westbrook and Anderson. On the other hand, Ashburn and Stiles denied parasite and tick alike.

However, Wilson and Chowning have been very considerably supported recently by Ricketts and King, who have been able to transmit the disease to monkeys and guinea-pigs by means of the adult of a tick which is now known as *Dermacentor occidentalis* Marx 1892, and McCalla and Brereton have transmitted the disease twice from man to man by the tick.

Ticks are rarely infected in Nature, and hence the disease is rare in man. The infection is in the gut and salivary glands and ovary. It is transmitted to young ticks.

Immunity can be acquired by guinea-pigs, and a serum made which will protect other guinea-pigs. The young of immune guinea-pigs are also immune. It is thought that a preventive vaccine is likely to be prepared.

The present position is that it is proved that Rocky Mountain fever is spread by *D. occidentalis*, but as to the parasite there is a doubt with regard to even its existence in the form described above; while Ricketts has recently described peculiar bacillus-like bodies.

The Tsutsugamushi Disease.

This disease, called 'Japanese river fever,' resembles in many respects Rocky Mountain fever, but by the careful researches of Ashburn and Craig is proved to be a different disease. It is spread by the bite of a larva of a *Trombidium* (the *Trombidiidæ* are the harvest-mites). Professor Ogata believes that the cause of the disease is a protozoön of the nature of a plasmodium; another theory is that of a bacterium, and another that it is due to a toxin in the mite. Ashburn and Craig have investigated these matters, and conclude that Ogata's plasmodium does not exist, and that the causative organism is as yet unknown.

Typhus Exanthematicus.

The causation of this disease is at present unknown. It is usually said to be non-inoculable, but recently Yersin and Vassal have communicated it by this method to a man by inoculating under the skin 0·5 gramme of blood taken from a person two days ill with the disease. The incubation was fourteen days, and a typical attack resulted.

With blood taken on the fifth day of the disease, inoculation failed at first, but on the second occasion the incubation was twenty-one days.

It has been said to be due to a fungus (*Rhizopus*), to diplococci, streptobacilli, and protozoa.

With regard to the latter, in 1892 Lewaschew described oval-shaped and flagellate organisms actively moving in the plasma of fresh blood. Gotschlich found what he considered to be a babesia in the blood, and thinks that the spread of the disease is probably due to a tick. Yersin and Vassal also think that it resembles a disease transmissible to man by the bite of a parasitic animal.

Sambon thinks that Rocky Mountain fever is only a local form of typhus fever, and that probably Japanese river fever is the same, and that the differences pointed out are illusory. Husband and McWalters support Sambon.

Hæmoglobinuric Fever.

Sambon has brought forward a theory that this disease (Blackwater fever) may be due to a minute babesia. More will be said about this theory under the heading of the disease.

Achromaticus Dionisi 1898.

Achromaticus vesperuginis Dionisi 1898.

This parasite was found by Dionisi in the noctule in 1898. Sambon classifies it as a babesia, but this is doubted by Nuttall and Graham-Smith, as well as by Dionisi, though they report pyriform endocellular parasites from blood films from bats of the genus *Vesperugo*, and Nuttall and Graham-Smith report four pyriform parasites in a corpuscle. Gonder, however, believes that it is in some intermediate position between the Plasmodidæ and the babesia, and Nuttall and Graham-Smith consider that further investigations are necessary before it can be classified. We agree with Gonder, and consider the parasite to be neither a babesia nor a plasmodium, and therefore return to Dionisi's original idea of a separate genus.

FAMILY 5. PLASMODIDÆ LÜHE 1906.

Synonyms.—*Gymnosporidia* Labbé 1894, *Acytosporidia* Wasielewski 1896, *Hæmomœbidæ* Ross 1899, *Acystosporea* Minchin 1903.

Definition.—Encystidæ, without a well-developed flagellum in any stage of the life-history. The trophozoite grows into the schizont, containing hæmozoin, which breaks up into a number of merozoites, which are usually said never to be flagellate.

The oökinete encysts and forms a typical oöcyst, which breaks up eventually into sporozoites. The genera of the Plasmodidæ are: *Plasmodium* Marchiafava and Celli 1885, *Laverania* Grassi and Feletti 1889.

Plasmodium Marchiafava and Celli 1885.

Synonyms.—*Oscillaria* Laveran 1881, *Hæmatomonas* Osler 1887, *Hæmatophyllum* Metchnikoff 1887, *Hæmamœba* Grassi and Feletti 1889, *Laverania* Grassi and Feletti 1889, *Cytamœba* Danilewski 1890, *Proteosoma* Labbé 1894, *Hæmosporidium* Lewkowicz 1897, *Cytosporon* Wasielewski 1901.

Definition.—Plasmodidæ, in which the gametocytes resemble more or less the schizonts by being round in shape.

Nomenclature.—Some remarks are perhaps necessary on the nomenclature. Laveran first used the term *Oscillaria* because he saw the flagellate form, which at that time was thought to be a *Polymitus* form because of its flagella. Later Laveran repudiated this term, which, indeed, could not be used, because it had already been applied to a plant. He then suggested the term 'hæmatozoon,' but this is objectionable, because the hæmatozoa are a group of parasites, and not a single genus. Metchnikoff suggested the term *Hæmatophyllum malariæ*, which is equally impossible; therefore the earliest distinctive term is 'plasmodium,' which was used by Marchiafava and Celli in 1885.

It is not a good term, because a plasmodium is generally considered to be a mass of protoplasm with several nuclei representing, not one single animal, but several.

General Account.—The malarial parasites may be taken as the typical examples of the Plasmodidæ.

The malarial parasite exists in nature outside the human body in certain species of different genera of the family Anophelinæ, a type of mosquito which is somewhat easily identified by its habit of projecting at almost right angles from the surface on which it stands. In the salivary glands of infected insects the malarial parasites are found as fine fusiform bodies, about 10 to 20 μ in length, and 1 to 2 μ in breadth, lying in the cells or in the duct. These fusiform bodies are called sporozoites, and consist of cytoplasm containing a central nucleus composed of chromatin.

The ends of the parasite are pointed, one being sharper than the other. They are capable of movement forwards, and of flexion into loops or curves. It may be that the sporozoites represent male, female, and indifferent parasites, or they may not; the question is still undecided.

When inoculated into man by a mosquito, they penetrate into the red blood cells, and develop into small endo-corpuscular parasites called the trophozoites, which at first are composed of cytoplasm and a nucleus.

This young trophozoite grows, throwing out pseudopodia for the purposes of nutrition, and presently a vacuole appears, converting the small parasite into a ring form, which, according to Schaudinn, is of benefit in enabling it to absorb nutriment quickly.

The vacuole does not keep pace with the growth of the parasite, and finally in the old form disappears. Early in the ring forms there appear granules of a black pigment, which used to be called melanin, but which has by no means the chemical characteristics of true melanin, as will be described under Malaria. This pigment has been named by Sambon 'hæmozoin'—a name which appears to us to be peculiarly suitable, and will therefore be used in this work. It is really of an excrementitious nature. The fully-grown trophozoite now ceases to be amœboid, and, becoming rounded off and full of pigment granules, is called the schizont, which has a subcentral nucleus. This nucleus now divides, so that parasites may be seen with two, three, four, five, six, up to twenty-four nuclei. The cytoplasm around these nuclei segments into small bodies called merozoites, each with a nucleus, but an unsegmented portion containing the hæmozoin, and called the residual mass, or *nucleus de reliquat*, is always left unsegmented (Fig. 39).

The blood-corpuscle now breaks up, and the merozoites, residual protoplasm, and pigment are liberated into the blood-stream, where the effete matter and some merozoites are taken up by the leucocytes and destroyed.

The merozoite usually tries to enter a red blood cell and to start again as a trophozoite, thus completing a cycle in the blood of the human being who is acting as host. This cycle is called the *cycle of Golgi*, or *schizogony*. Sometimes more than one merozoite will enter a cell, thus giving rise to multiple infection. In such a case they are generally of the same age, but this is not invariable. In the red cell, under these conditions of multiple infection, some observers have thought that the young trophozoites might conjugate; but this, together with the suggestion of further division of the merozoite, we believe to be incorrect, though it must be admitted that forms with a double nucleus can be seen. When such a binucleate form is seen nowadays, it makes the observer think seriously of a possible flagellate origin, and inclines him to support Sambon and Hartmann's classification, but never, as far as we know, has anyone seen a flagellate merozoite in human malaria.

It will be seen that in going through the process of schizogony one sporozoite becomes several merozoites, and that each of these may again become several merozoites, so that the infection grows unless kept in check by phagocytosis, and perhaps chemical action or quinine treatment.

Each parasite means a red cell destroyed and so much toxin liberated into the blood-stream. Hence in a certain number of days (eight to twelve, as a rule) the parasites will have increased to such a degree that their collective toxins, acting upon the organs of the body, upset the metabolism and produce an attack of fever. This period of eight to twelve days is the incubation period of the disease.

It is possible that all the sporozoites develop into schizonts, and there is at present no evidence that they develop into male or female forms directly. If they do not do this, then the merozoites must differentiate sexually; for in about a week male and female forms can be seen in the blood-stream, and, moreover, very young stages can be observed.

The earliest form of a sexual parasite is like an ordinary merozoite, but it grows very slowly, and it never possesses a vacuole, and as it grows its protoplasm becomes heavily pigmented and granulated in the female, and lighter and clear in the male. The result is to produce a female type of parasite called the macrogametocyte, or a male type of parasite, the microgametocyte. So that there are three types of parasite—the indifferent or schizont, the female, and the male.

The macrogametocyte is characterized by possessing a small, more or less rounded nucleus eccentrically placed and poor in chromatin, and a cytoplasm full of granules and pigment.

The microgametocyte is characterized by having a large nucleus, extending like a band across the cytoplasm, and much chromatin, a clear protoplasm, and less pigment.

The macrogametocyte and microgametocyte are the means of propagating the parasite in the mosquito, and if they fail to reach the gut of this insect the microgametocytes die off.

The macrogametocytes, on the other hand, are extremely persistent, and can wait in the body for a long time until some chill or accident lowers its resistance, when they become active and develop merozoites by parthenogenesis, thus accounting for the relapses and the recurrences of malaria, even months and years after having left a tropical country. Hence in malaria there is a latent phase which is capable of lasting an unknown time—at least one to three years, perhaps longer ; but upon this subject more will be said later, and, indeed, more information is urgently needed.

In developing parthenogenetically, the nucleus of the macrogametocyte divides into two portions, one rich and the other poor in chromatin. The pigment granules gather round the pale nucleus, and with it the surrounding cytoplasm and hæmozoin form a sort of *nucleus de reliquat.* The rest of the protoplasm, rendered clearer by loss of its hæmozoin, contains the nucleus rich in chromatin, which now divides like the nucleus of a schizont, and forms merozoites, which, escaping from the red cell, infect red corpuscles, and start the cycle of schizogony anew (*vide* Fig. 43).

Etheogenesis is unknown in the malarial parasite.

If a female mosquito (the male does not suck blood) belonging to certain of the genera of the Anophelinæ sucks the blood of a person in whom both macro- and microgametocytes are to be found, a new cycle is started in that mosquito. This cycle is sporogony, which is characterized by being a sexual process. Changes now appear in the macro- and microgametocyte, which are thought by Schaudinn to be brought about by the alteration in temperature.

The macrogametocyte, escaping from its red cell, undergoes reduction by division of its nucleus once or twice, forming polar bodies. The reduced gametocyte is now called the macrogamete.

Similarly the microgametocyte undergoes changes, for chromidial masses separate from its nucleus and travel to the periphery of the parasite, from which thin threads of protoplasm now project (Figs. 40, 41, and 42).

These threads, which vary from four to six in number, lash about vigorously, moving the whole parasite, which therefore whirls about, and it and its processes, called flagella, were looked upon as a polymitus ; hence this stage is often called the polymitus stage.

The threads break off, and are now called microgametes. Each microgamete is composed of a long, tapering thread of protoplasm capable of bending and moving rapidly. Its chromatin is spread along it in dots or bars, and hence the whole structure somewhat resembles a spirochæte, but there is no undulating membrane.

A microgamete now conjugates with a macrogamete, the male and female pronuclei fusing to form a synkaryon, and the resulting zygote is called an oökinete. This zygote elongates, and its anterior extremity, which is more or less clear of hæmozoin, becomes pointed; the nucleus lies in the middle, and the posterior end contains most of the pigment, which may be largely cast off or may be retained.

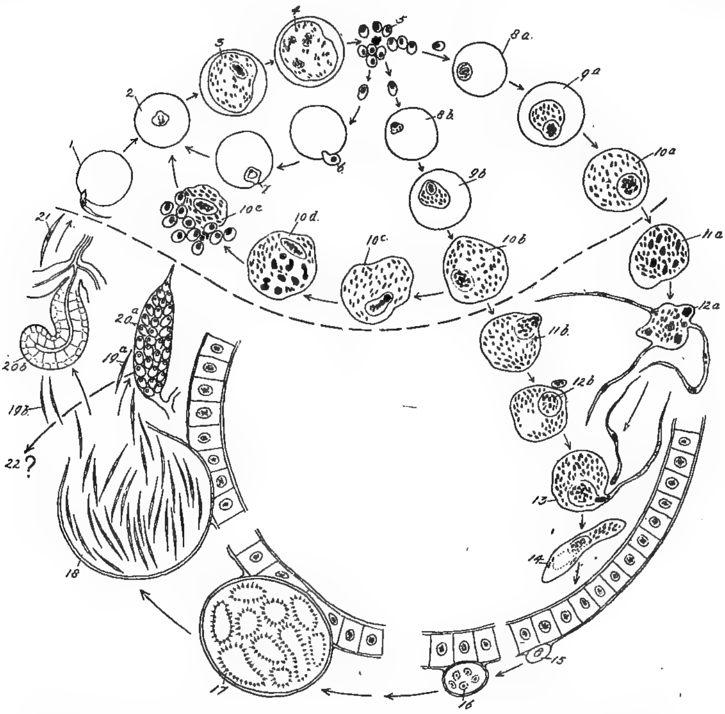


FIG. 93.—DIAGRAM OF THE LIFE-CYCLE OF PLASMODIUM VIVAX.

1, Sporozoite entering red cell; 2, trophozoite; 3-4, schizont; 5, merozoites; 6, merozoites entering red cell; 7, young trophozoite; 8*a*-10*a*, development of a microgametocyte; 8*b*-10*b*, development of a macrogametocyte; 10*b*-10*e*, parthenogenesis; 11*a*-12*a*, formation of a microgamete; 11*b*-12*b*, formation of a macrogamete; 13, zygosis; 14, oökinete; 15, oöcyst; 16, formation of sporoblasts; 17, formation of sporozoites; 18, cyst ruptured and sporozoites escaping; 19*a*, sporozoites infecting the ovary; 19*b*, sporozoites infecting the salivary glands; 21, sporozoites escaping from the salivary duct and entering the human skin; 22, this indicates that the further development of the sporozoites infecting the ovary is unknown.

It now pierces the epithelium of the mosquito's stomach, below which it comes to rest, and forms a thin cyst-wall, and is called the oöcyst. This now grows rapidly, and its nucleus divides into a large number of daughter nuclei, around each of which the protoplasm gathers, forming the sporoblasts, which are somewhat connected together (Fig. 93).

The nucleus of each sporoblast now divides into several small nuclei. These travel to the periphery, which grows out into a series of small projections, each of which takes a chromatin particle with it. Each of these projections is a sporozoite, so that each sporoblast forms a large number of sporozoites, and leaves a residual mass of pigment and cytoplasm undivided. The cyst, now enormously enlarged, bursts, and the sporozoites escape into the cœlome of the insect, which in this case is a hæmocœle, and therefore they enter the blood, and are carried by it probably all over the insect's body. Certainly they are seen in the thoracic muscles, but finally they find their way to the salivary glands, and so to a new host or to the eggs, and so probably to a new generation of mosquitoes.

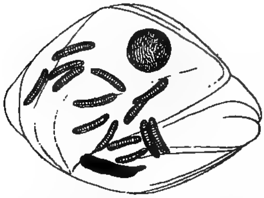


FIG. 94.—AN OÖCYST SHOWING ROSS'S 'BLACK SPORES,' NOW KNOWN TO BE PROTOZOA BELONGING TO THE GENUS NOSEMA.

(After Grassi.)

Sporogony takes about ten to twelve days, during which the mosquito will have sucked blood three or four times.

Abnormal Forms.—In mosquitoes, whether infected by malarial parasites or by Proteosoma, peculiar bodies, called 'black spores' by Ross, are sometimes found in the stomach wall, which are now known to be protozoal parasites of the genus *Nosema*, which have invaded the oöcysts, and are therefore hyperparasites.

Classification.—A number of species, increasing gradually, belong to this genus, among which are two of the malarial parasites, *P. vivax* and *P. malariæ*.

Plasmodium vivax Grassi and Feletti 1890 (Plate I.).

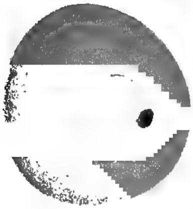
Synonyms.—*Hæmamœba vivax* Grassi and Feletti 1890, *H. malariæ var. magna* Laveran 1900, *H. malariæ var. tertianæ* Laveran 1901, *Plasmodium malariæ var. tertianæ* Celli and Sanfelice 1891, *P. malariæ tertianum* Labbé 1899, *Hæmosporidium tertianum* Lewkowicz 1887.

Plasmodium vivax is the parasite of tertian malarial fever, and derives its specific name from its energetic amœboid movements, which probably take place for purposes of nutrition.

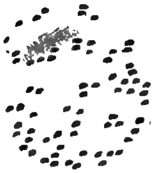
Its schizogony has been well studied by Golgi and Schaudinn, and its sporogony by Grassi, Bignami, and Bastianelli.

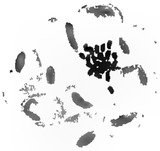
The whole process of the schizogony of *P. vivax* can be summarized as follows: During the first twenty-four hours after the entry of the sporozoite or merozoite into the red cell the little trophozoite, which at the beginning is about one-third the size of

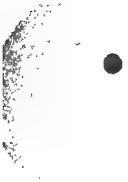
PLATE I.


1 *a*

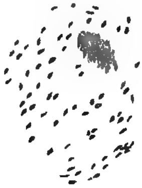
2 *a*

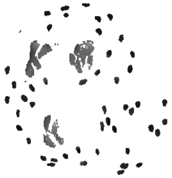

3 *a*

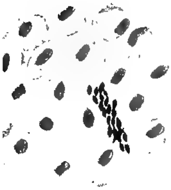

4 *a*


1 *b*

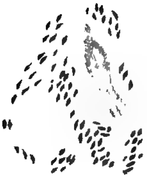
2 *b*

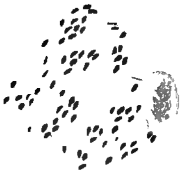

3 *b*

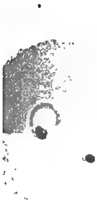

4 *b*

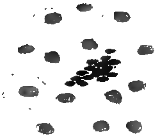

5 *b*

6 *b*


7 *b*


8 *b*


1 *c*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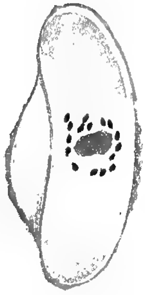
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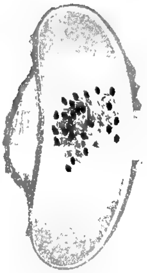
4 *c*

the erythrocyte, grows rapidly, absorbing nutriment from the red cell by its pseudopodia and by the large surface of cytoplasm exposed, owing to the size of the vacuole.

Hence, not merely does it increase in size, but it acts deleteriously upon the enclosing cell, which loses its hæmoglobin, turns pale and degenerates, as is evident by its becoming swollen owing to the absorption of fluid, and by showing, on staining with any modification of Romanowsky, a dotted appearance due to red granules called Schüffner's dots. These dots can be seen in red cells affected by other plasmodia—*e.g.*, *P. canis* in the dog. In growing, it gives rise to a quantity of hæmozoin, which appears as fine, reddish-brown granules, often seen in active movement due to currents in the cytoplasm of the parasite. In about thirty hours it becomes rounded off as the schizont (Fig. 39), 8·5 μ in diameter.

From the thirtieth to the forty-eighth hour the fully-grown schizont undergoes sporulation, when it will be noticed that fifteen to twenty merozoites are formed, while the hæmozoin granules are packed together, either into the centre or towards the periphery of the parasite. It will also be noted that the red cell is now considerably swollen and almost colourless.

About the forty-eighth hour the remains of the corpuscle disintegrate, and the merozoites (size 1·5 μ), hæmozoin, etc., escape.

So that *P. vivax* occupies forty-eight hours in the process of schizogony. As curiosities, it may be mentioned that a trophozoite or a schizont may be seen in the same red cell as a gametocyte.

Sporogony.—The development in the mosquito was first worked out in *Anopheles claviger*.

The development of the gametes, and the fertilization of the macrogamete, and the structure of the oökinete, have been carefully described and figured by Schaudinn (*vide* Figs. 40, 41, and 42). In about forty hours after the mosquito has been fed, the oöcyst can be found as a round transparent body with strands of yellowish hæmozoin scattered throughout it, lying in the stomach-wall beneath the epithelium, and covered over by the musculo-elastic layer of the gut. Its wall is seen to be well defined—*i.e.*, the oökinete has become encysted. By this time the chromatin will have divided into small masses.

On the third day it will have become from one-third to one-fourth larger, and the cyst-wall will be more distinct, and the imperfect segmentation of the protoplasm around the nuclei can be seen. The hæmozoin is seen gathered into little masses lying between the segments of the cytoplasm, which are the sporoblasts. The first stages of the formation of sporozoites may also be observed.

During the fourth day the size increases about a fourth, and the nuclei and their surrounding protoplasm will have formed some twenty to thirty sporoblasts, whose periphery will be marked by a palisade of forming sporozoites.

Between the fourth and fifth day the cysts (50 μ in diameter) full of sporozoites (size 14 μ) will be seen to be projecting into the cœlome.

After the seventh day the oöcyst ruptures, and the sporozoites escape and find their way to the salivary glands, in the cells of which they lie, mainly in those of the mid or poison gland. Thus, about the tenth to the twelfth day after infection the mosquito is ready to spread the disease by its bite, and the cycle of sporogony is complete. It must be remembered that Schaudinn observed infection of the mosquito's egg, but whether the parasite penetrates into the larva, and from that to the pupa, and thus into a second generation, is not known.

Plasmodium malariæ Laveran 1881 (Plate I.).

Synonyms.—*Hæmamœba malariæ* Grassi and Feletti 1890, *H. laverani var. quartana* Labbé 1894, *H. malariæ var. magna* Laveran 1900, *H. malariæ var. quartanæ* Laveran 1901, *Plasmodium malariæ var. quartanæ* Celli and Sanfelice 1891, *Hæmosporidium quartanæ* Lewkowicz 1897, *Plasmodium malariæ quartanum* Labbé 1899, *P. golgii* Sambon 1902, and *Laverania malariæ* Jannescó 1905.

Schizogony.—The young trophozoite, which is smaller than *P. vivax*, forms a compact ring, which lies in an unaltered erythrocyte, and shows, as a rule, but little pseudopodial activity. Very soon hæmozoin appears in the form of dark rodlets.

After the first twenty-four hours the parasite is found to be much larger, and the hæmozoin more abundant. The granules of pigment will be noticed to be gathered at the periphery, and to be very dark in colour, and non-motile. The red cell tends, if anything, to become smaller and darker. In about sixty hours the trophozoite will have become the full-grown schizont, which is a large, round, pigmented body surrounded by a rim belonging to the corpuscle. During the next twelve hours its nucleus divides up into six or twelve nuclei, around which the cytoplasm gathers, while the hæmozoin is driven into the centre, and the appearance of a daisy is produced by the central block of hæmozoin and the regular arrangement of the merozoites around it (size 6 μ).

The merozoites (size 1·75 μ) are now set free, and, as a rule, many of them appear to be killed off, and not to be able to affect the red cells. More rarely they go on increasing in number, and recently have been said to cause death in a case (Leishman), but a severe infection is not usual.

The whole schizogony takes place in the peripheral blood, and occupies seventy-two hours.

Sporogony.—Gametocytes are very rarely seen, and only after the disease has lasted a long time, but Vida has recently described all stages of their development as seen in the peripheral blood.

They begin as small forms with a central nucleus but no vacuole, and soon become pigmented, the fully-grown macrogametocyte being a little larger than a normal corpuscle. Its dark cytoplasm is heavily pigmented, especially at the periphery, at which the nucleus is also placed. The corpuscle forms but a small rim around the parasite.

The microgametocyte shows the usual structure already described, but is less pigmented, and has a clearer cytoplasm. The corpuscle is not enlarged, as in the case of the macrogametocyte, and much more of it is visible around the parasite. The formation of the microgametes has been observed, but the infection of the mosquito is difficult to bring about, though the development in the mosquito has been traced by Bignami and Bastianelli. The oöcyst is characterized by the pigment, which is black, coarse, and gathered into a clump. The cycle of development is the same as in *P vivax*, but takes about eighteen to twenty-one days to be completed after infection in mosquitoes which were kept at a temperature of about 22° C. This appears to be the degree of heat at which the process takes place best. At the end of that time the completely developed sporozoites can be seen.

Plasmodium danilewskyi Grassi and Feletti 1890.

Synonyms.—*Laverania danilewskyi* Grassi and Feletti 1890, *Hæmamœba relicta* Grassi and Feletti 1891, *Cytosporon malariæ avium* Danilewskyi 1891, *Proteosoma grassii* Labbé 1894, *Plasmodium relictum* Sergent 1907.

This parasite was discovered by Grassi in the blood of birds in Italy, and causes death in partridges in Hungary. It affects sparrows in India, and is the form in which Ross first traced the development of a plasmodium in a mosquito. It occurs in Ceylon, and is common in Africa.

The young trophozoite becomes pigmented, and, displacing the nucleus, grows into the schizont, which forms about nine merozoites.

The macrogametocyte has but little chromatin in its nucleus, which is rounded, while the microgametocyte has an elongated, darkly-staining nucleus.

These develop in *Culex fatigans*, *C. nemorosus*, or some other species, when in about twelve to fifteen hours oökinetes are seen, and in about one to two days well-developed oöcysts are present in the stomach in the form of round, transparent cysts, with hæmozoin scattered through them.

In three to four days the oöcysts have increased in size, and sporoblasts have appeared, and even sporozoites are forming.

In nine to ten days the oöcyst has become fully developed and bursts, and the sporozoites can first be seen in the muscles of the thorax, and then in the salivary glands, in which they lie principally in the central or poison lobe. The black spores already mentioned can be noted in the stomach, and, according to Stephens and Christophers, in either the thoracic muscles or in the salivary glands.

No traces of parasites have been found in the larvæ or second generation of *Culex*.

Plasmodium kochi Laveran 1899.

This plasmodium is found in chimpanzees (*Anthropopithecus troglodytes* Gm.), and in monkeys in Africa and in Ceylon; in the latter it causes illness and death. The spleen and bone-marrow are found pigmented. It is said not to be inoculable.

Plasmodium pitheci Halberstaedter and Prowazek 1907.

Found in the ourang-outang (*Simia satyrus*) and the chimpanzee, in which the trophozoites resemble *P. vivax* and the gametes *P. malariæ*. Schüffner's dots can be seen.

Plasmodium inui Halberstaedter and Prowazek 1907.

In *Macacus cynomolgus* L. and *M. nemestrinus* L. It is like *P. pitheci*, but the hæmozoin is in the form of fine yellow granules. Merozoites, twelve to sixteen in number. Schüffner's dots absent.

Plasmodium cynomolgi Mayer 1907.

In *M. cynomolgus* L. Merozoites, eight to thirteen. Schüffner's dots present.

Plasmodium bovis Kolle 1898.

In cattle in South Africa, in which they produce remittent fever and severe anæmia.

Plasmodium canis Castellani and Chalmers 1908.

Found in pariah dogs in Ceylon. Resembles *P. vivax*. Schüffner's dots present. Fig. 95 shows the schizogony of this parasite, and Fig. 96 the gametocytes.

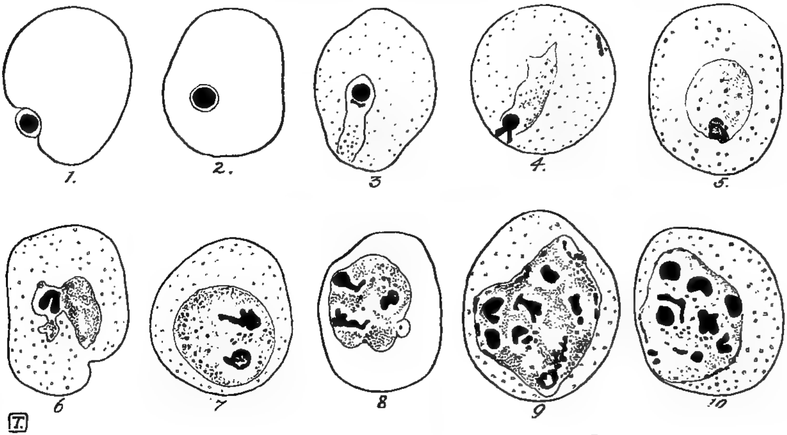

FIG. 95.—PLASMODIUM CANIS CASTELLANI AND CHALMERS.

1-2, Merozoite entering the corpuscle; 3, young trophozoite (the red cell shows Shüffner's dots); 4-6, trophozoites, enclosing cells showing Shüffner's dots; 7-10, schizonts showing various stages of nuclear division prior to the formation of the merozoites.

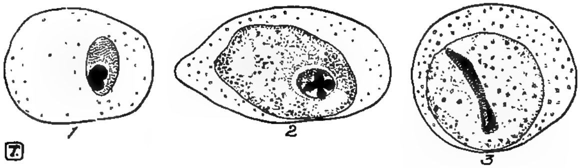

FIG. 96.—PLASMODIUM CANIS CASTELLANI AND CHALMERS.

1, Young gametocyte; 2, Macrogametocyte; 3, microgametocyte.

Other Forms.

In Mammals.—*P. murinum* Dionisi 1898, in *Myotis myotis*, *P. monosoma* Vassal 1907, in *Vesperugo abramus*; *P. vassali* Sambon 1907, in *Sciurus griseimanus* (a squirrel).

In Birds.—*P. majoris*, in *Pavus major*; *P. vaughani* Novy and MacNeal 1904, in *Merula migratoria*.

In Lizards.—*P. simondi* (*Hæmocystidium s.*) Castellani and Willey, 1905, in the gecko (*Hemidactylus leschenaulti*) in Ceylon. *P. diploglossi* Aragao and Neiva 1909 in *Diploglossus fasciatus*; *D. B.* and *P. tropiduri* Aragao and Neiva 1909 in *Tropidurus torquatus* Wied in Brazil.

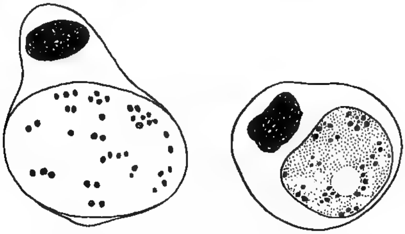

FIG. 97.—PLASMODIUM SIMONDI.
(After Castellani and Willey.)

Laverania.

Plasmodidæ, in which the gametocyte is dissimilar from the schizont, appearing in the form of a crescent.

Laverania malariæ Grassi and Feletti 1890 (Plate I.).

Synonyms.—*Hæmamœba malariæ* Laveran 1890, *H. præcox* Grassi and Feletti 1890, *H. laverani* Labbé 1894, *H. immaculata* Grassi and Feletti 1891, *Plasmodium malariæ var. quotidianæ* Celli and Sanfelice 1890, *P. præcox* Doflein 1901, *P. immaculatum* Schaudinn 1902, *P. falciparum* Blanchard 1905, *Hæmomenas præcox* Ross 1899, *Hæmosporidium undecimanæ* Lewkowicz 1892, *H. sedecimanæ* Lewkowicz 1892, *H. vigesimotertianæ* Lewkowicz 1892, *Hæmatozoon falciparum* Welch 1897.

The young trophozoite begins as a very small parasite, which quickly forms a ring, of which the size is only one-sixth to one-seventh of the diameter of the enclosing red cell. This quickly grows into an oval form, which becomes pigmented, while the enclosing erythrocyte in stained preparations may show the so-called Maurer's dots, the significance of which is not understood.

The fully-grown schizont (size 4·5 μ) is but rarely seen in the peripheral blood, and the segmentation into merozoites (size 0·7 μ) nearly always takes place in the internal organs, when eight to ten or fifteen are formed. While this is in progress there is a great tendency for the red corpuscles to cling together and to the wall of the vessel, and hence to give rise to obstruction of the circulation, which produces the perniciousness of the fevers due to this parasite.

Schizogony takes from thirty-six to forty-eight hours to be completed.

The gametocytes are characterized by being crescent-shaped and large, with the remains of the red cell stretched round them. The hæmoglobin of the cell is often seen lying in juxtaposition to the parasite, while the remaining portion of the corpuscle is almost colourless.

The macrogametocyte is characterized by its long thin shape, its darker cytoplasm, and its compact chromatin, around which the hæmozoin forms a ring or mass.

The microgametocyte has a shorter and broader shape, more hyaline cytoplasm, with more diffused chromatin and more scattered pigment.

The formation of the macrogametocytes and the microgametocytes has been followed, and the oöcyst and sporozoites are easily seen, especially in mosquitoes on the West Coast of Africa, being clear, round parasites with the black hæmozoin gathered into a clump, with a single nucleus on the second day, and with considerable increase in size on the third to fourth day, when the wall of the cyst can be easily seen.

On the fifth to sixth day the enormous increase in size is noted, and the sporoblasts with commencing sporozoites. On the seventh day the cyst is full of sporozoites, which pass on the following days to the salivary glands.

DIFFERENTIAL CHARACTERS OF THE MALARIAL PARASITES.

Character.	P. malariæ.	P. vivax.	L. malariæ.
Schizogony ..	Completion in seventy-two hours.	Completion in forty-eight hours.	Completion in forty-eight hours or less.
Young trophozoite	Young trophozoite, smaller than *P. vivax*, larger than *L. malariæ;* movements rather slow; pseudopodia not marked or long.	Young trophozoite, large; very actively motile; long pseudopodia.	Young trophozoite, small; actively motile.
Hæmozoin ..	Granules coarse, sluggish; peripherally arranged; dark brown.	Granules fine; movement marked.	Granules fine and scanty; often motionless.
Schizont ..	Smaller than red corpuscle.	Larger than red corpuscle.	Much smaller than red corpuscle.
Merozoites ..	Six to twelve, regularly arranged in a rosette.	Fifteen to twenty, regularly arranged.	Eight to fifteen, arranged irregularly.
Gametocytes	Resemble sporonts, but larger.	Resemble sporonts, but larger.	Crescentic in shape.
Erythrocytes	Almost normal.	Pale and swollen.	May be small and dark.

APPENDIX.—SPIROCHÆTACEA Fantham 1908.

Synonyms.—*Proflagellata* Doflein; *Spiroschaudinnidæ* Sambon 1907; *Spiroflagellata* Krzysztalowicz and Siedlecki 1907.

Definition.—Plasmodromata, generally parasitic, in form narrow, wavy, and thread-like, with or without an undulating membrane. The cytoplasm is divided into endoplasm and ectoplasm, and is bounded by a flexible, chitinous periplast. The nucleus consists of a spiral achromatic filament, on which are arranged transverse bars or rodlets of deeply staining chromatin.

Remarks.—The Spirochætacea are closely related to the Binucleata, and especially to the Trypanosomidæ.

The Treponemata are joined to the spirochætes because of their general resemblance, though it must be admitted that no nucleus of the nature of the spirochæte nucleus has yet been described, and the spirals are apparently not due to movement.

The Spirochætacea are potent factors in the production of disease, for *S. recurrentis* is the cause of one type of relapsing fever, *S. carteri* of another, *S. duttoni* of another, and *S. novyi* of yet another, while the Treponemata are the cause of syphilis and yaws.

The Spirochætacea may be divided into two families: the Spirochætidæ Ehrenberg 1833—Spirochætacea with an undulating membrane; the Treponemidæ Schaudinn 1905—Spirochætacea without an undulating membrane.

Spirochætidæ Ehrenberg 1883.

Definition.—Spirochætacea with an undulating membrane. Body may be ribbon-shaped on transverse section.

Remarks.—There is a difference of opinion as to whether these organisms are protozoa or bacteria. At first they were universally regarded as bacteria, but in 1904 Schaudinn's paper on the leucocytozoon in the little owl showed that this body, after fertilization in the gut of *Culex pipiens* and subsequent asexual division, produced a large number of minute forms which he at the time considered to be spirochætes, and he further concluded that in all probability all spirochætes were stages in the life-history of intracellular parasites. In 1905, however, he came to the conclusion that the spirochæte forms which he had seen develop from *T. ziemanni* were trypanosomes. In fact, there is one great point of difference—the forms which he described possess a distinctly consolidated nucleus, whereas spirochætes do not. After this the view that spirochætes were bacteria was revived, particularly by Novy and Knapp, on the following grounds:

1. Absence of trophonucleus.
2. Transverse division.
3. Rapid multiplication.
4. Absence of plasmolysis with distilled water.

5. Persistence of form when acted upon by heat.
6. The production of active immunity.
7. The absence of aerotropism—*i.e.*, the tendency to mass round a bubble of air.

On the other hand, there is a growing feeling among biologists that spirochætes are really protozoa—*e.g.*, Doflein, Minchin, Sambon, Nuttall, Fantham, and Krzysztalowicz and Siedlecki. Fantham points out that the strongest arguments in favour of their being bacteria are:

1. Diffuse character of nucleus somewhat like *Bacillus bütschlii.*
2. The possible occurrence of transverse fission.
3. The absence of a typical kinetonucleus;

while the points in favour of their belonging to the protozoa are:

1. The possession of an undulating membrane.
2. The occurrence of longitudinal division (denied by Schellac).
3. The non-plasmolysis.
4. Inability to find artificial media on which they can grow.

We consider that they are protozoa, and, further, that they are related to the trypanosomes. Spirochætes are, however, distinctly peculiar, particularly with regard to their diffuse nucleus; but there appears to be almost a series from the diffuse nucleus of the bacteria through the achromatic spiral, with its attached chromosomes of the spirochætes, to the condensed nucleus of the higher protozoa. Schellac derives them phylogenetically from the oscillatory cyanophees genus spirulina.

Spirochætes vary much in size, from *Spirochæta recurrentis*, which is 8 μ in length, to *S. balbianii*, which may be 150 μ in length and 2 to 3 μ in thickness. The type species *S. plicatilis* was found in muddy water by Ehrenberg in 1833, and was said by Schaudinn in 1905 to possess an undulating membrane. Sambon, however, considers that this so-called type-species is quite different to *S. recurrentis*, and should be placed in a different group therefrom. The most carefully studied types are *S. balbianii* Certes 1882, found in oysters, and *S. anodontæ* Keysselitz 1906, both of which have been the subject of research by Fantham, whose results are here followed. These organisms are long, wavy, and thread-like, composed of cytoplasm, which can be differentiated into an ectoplasm, which is generally converted into a thin, flexible, chitinous membrane, the periplast, which is continued laterally into a spirally arranged, undulating membrane containing longitudinally arranged fibrillæ, and having a thickened border composed of chromatin. The longitudinal fibrillæ are composed of eight to nine principal and numerous secondary fibrillæ, which are contractile, and are called 'the myoneme fibrillæ,' corresponding, it is believed, to the myonemes of trypanosomes (Fig. 98).

The undulating membrane helps in locomotion, which is rapid, and takes place by a wave-like flexion of the body, which causes forward movement, and a corkscrew motion, produced by the spiral winding of the membrane enabling the parasite to bore its

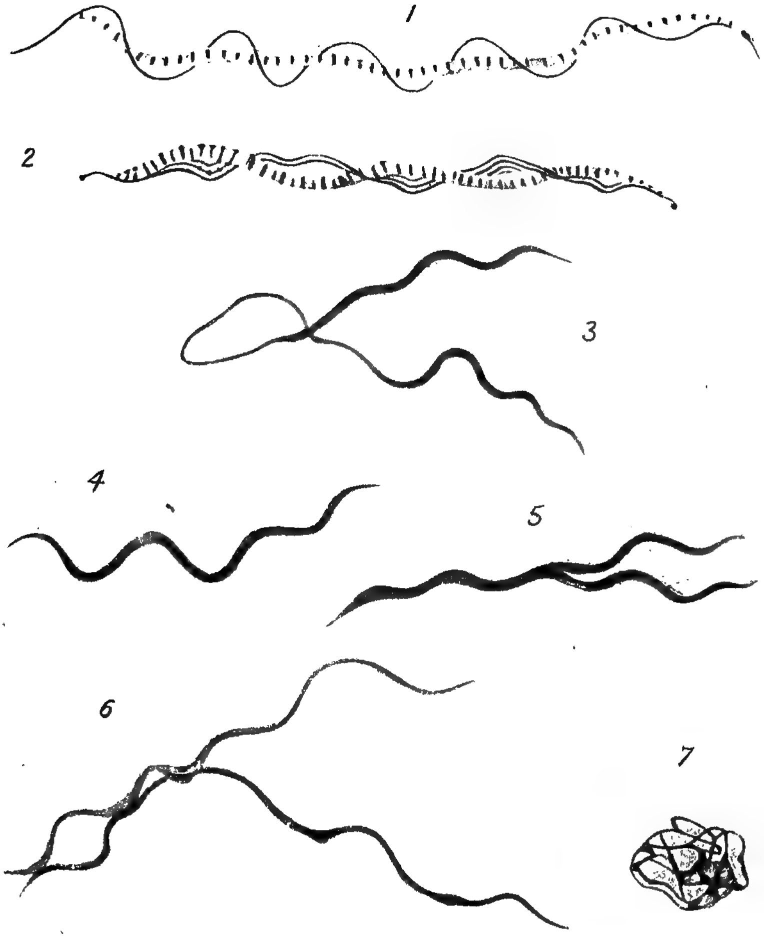

FIG. 98.—SPIROCHÆTES.

1, *Spirochæta anodontæ*, showing the undulating membrane and chromatic ars (after Fantham, *Quarterly Journal of Microscopical Science*); 2, *Spiro-hæta balbianii*, showing fibrillæ in undulating membrane (after Fantham); -7, *Spirochæta duttoni* (after Breinl, *Annals of Tropical Medicine and Para-itology*); 4, shows the uncoloured transverse band; 5, longitudinal division; , possible male and female forms; 7, encystment.

way through the débris amidst which it may be living. A spirochæte can move backwards or forwards indifferently.

The endoplasm is slightly more granular than the ectoplasm, and contains a diffuse nucleus, which appears to consist of an achromatic filament with bars of chromatin.

In addition to this nucleus there is a dot of chromatin (basal granules) at each end of the periplast in *S. balbianii*, and only at one end in *S. anodontæ;* in the latter a short, stiff process of periplast projects from it, which is considered by some observers to be a flagellum.

Reproduction takes place by both longitudinal and transverse divisions; it has been described by Fatham and Porter in *S. recurrentis*, *S. anadontæ*, *S. balbianii*, and *S. duttoni*. The basal granule first divides, and then the membrane, followed by the cytoplasm, as far as one end, which does not divide at once, but later, thus completing the act of asexual reproduction.

Encystment and conjugation have been described, but are regarded as doubtful, and so are the occurrence of broad female forms and narrow male forms.

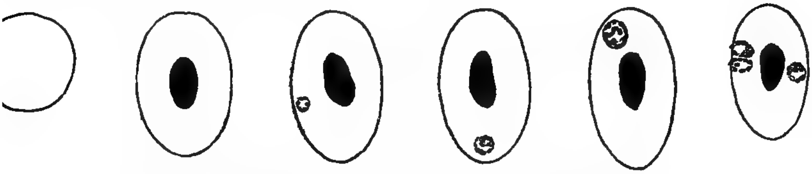

FIG. 99.—SCHIZOGONY OF SPIROCHÆTA MARCHOUXI.
(After Sambon.)

With regard to encystment, Breinl states that, just before the crisis in the fever, *S. duttoni* in the spleen and bone-marrow becomes thinner, and rolls itself up into complicated skein-like forms, which become surrounded by a thin cyst-like wall, inside which it becomes more and more indistinct, and finally breaks up into small granules, which are thought to be the forms which develop into new spirochætes. Sambon pointed out that the peculiar bodies described by Balfour in the blood of Sudanese fowls were rolled-up spirochætes breaking up into granules, which is probably a kind of fragmentation (schizogony).

With regard to conjugation and the cycle of sporogony, still less is known. In the case of *S. duttoni* it may take place in the tick.

Classification.—One genus and many species. Sambon has recently suggested that two genera should be distinguished—viz., a non-parasitic **Spirochæta** Ehrenberg 1833, and a parasitic **Spiroschaudinnia** Sambon 1907, a division which will probably be recognized in a few years.

Spirochæta recurrentis Lebert 1874.

Synonym.—*S. obermeyeri* Cohn 1875.

This spirochæte was discovered by Obermeyer in cases of relapsing fever in Berlin. It exists in the blood in short and long forms. The short forms, which are from 7 to 9 μ in length, are probably early stages. The long forms, 16 to 19 μ, result from multiplication or agglutination. The latter condition in a hyperimmune blood may lead to forms 18 to 100 μ in length, brought about by agglutination of two or more cells end to end. The width is 0·25 μ. The number of spirals in the short form, which is considered to be one cell, is two to three.

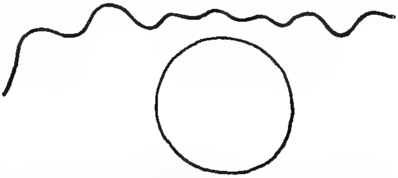

Fig. 100.—Spirochæta recurrentis, with Outline of Red Corpuscle for Comparison.

The short form is said by Novy and Knapp to have a long flagellum at one end, while the other has a faint appendage. The presence of flagella in this as well as in other spirochætes is denied by Nuttall.

No definite structure has been made out in this spirochæte, which is pathogenic to man, monkeys, rats, and mice; but these latter have to be infected from a monkey. Rabbits or guinea-pigs are not susceptible. It is found in the peripheral blood during the attacks and relapses, but not in the intermission, unless occasionally after very protracted search. It can also live in the bed bug—*Cimex lectularius*—for some days, and Nuttall has succeeded on one occasion in transmitting *S. recurrentis* from mouse to mouse by the bites of the same bug. Positive results have also been obtained by Sikul in Odessa.

Spirochæta duttoni Novy and Knapp 1906.

Synonyms.—*Spirillum duttoni* Novy and Knapp 1906; *Spirochæta duttoni* Todd 1906.

This spirochæte is the cause of the African tick fever. Its length is variously described; thus Novy and Knapp say that the young forms are 16 μ in length, while Breinl and Kinghorn make them 24 μ in length and 0·45 μ in width when fully grown. The number of spirals varies from two to three to eight to ten, with a width of 2·2 μ. The parasite is ribbon-shaped on transverse section, and though it is often in spirals, may be simply waved. The two ends are pointed.

The central core is seen to consist of lighter and darker portions, which correspond to the chromatic and the achromatic portions of the nucleus. The chromatic portion can break up into granules, when the parasites begin to disappear from the circulation.

The periplast is well marked, but there is great doubt as to the presence of an undulating membrane. Breinl, who has studied the subject carefully, could not definitely define one, but Dutton and Todd have seen it in blood taken directly from the circulation in man, or animals, or from the gut of *Ornithodoros moubata.* A small uncoloured transverse band is often to be seen in specimens stained by Giemsa lying across the parasite, about one-third its length from one end.

Reproduction can take place by longitudinal and transverse division. In the former the parasite thickens and then divides from one end, while in the latter the parasite increases in length and divides in the middle. Some authors deny the occurrence of transverse division, but this is untenable after Fantham and Porter's experiments.

There is, however, another and but little known method of reproduction, which appears to be analogous to spore-formation.

Just before the crisis, when the blood is swarming with parasites, they can be seen, according to Breinl, in the spleen and bone-marrow, and more rarely in the liver, coiling themselves up, and either showing a swollen appearance, or becoming thinner and rolling themselves into more and more complicated skein-like forms, which may be engulfed by phagocytes in the spleen, but in other organs become more regular and surrounded by a thin cyst-wall, the interior of which is filled with faintly blue-staining plasma.

In this cyst the parasite becomes more and more indistinct, and at a later stage small red granules are to be seen, which are thought to be the cause of the infection in the blood when filtered through a Pasteur-Chamberland filter. Therefore, according to the latest investigations by Breinl, the life-history of the parasite has two well-defined stages in the vertebrate. In the first it is found free in the liquor sanguinis in its typical form; in the second it enters a cell, and becoming coiled, its chromatin breaks up into a number of granules, each of which is believed to become a new spirochæte.

The stage in the liquor sanguinis is associated with the febrile attacks, and that in the cells with the apyrexial intervals.

S. duttoni is conveyed to man and animals by the bites of a tick, *Ornithodoros moubata*, in the gut of which it becomes differentiated into three types — one slender, another stout, and a third very long—while other forms can be seen coiled in the white and red cells of the ingested blood, and within the cells of the alimentary canal or Malpighian tubules.

The chromatin of these forms becomes minutely divided into fine or coarse granules, which possibly may become comma-shaped masses of chromatin, and grow into small spirochætes. The tick remains infective for a very long time—according to Möller, as long as eighteen months—and the infection can be passed through the eggs into a new generation of ticks, as has been demonstrated by Dutton and Todd; while according to Möller, ticks may remain infective to the third generation, even if the second generation have only fed on clean animals.

Fülleborn and Mayer (1907) failed to transmit *S. duttoni* by means of *Stegomyia calopus* (fasciata).

Attempts to cultivate *S. duttoni* as well as the other spirochætes have failed, although Levaditi has observed them to multiply when enclosed in collodion sacs placed in the peritoneal cavity of rabbits. Recently, however, Duval and Todd have succeeded in cultivating *S. duttoni* on a medium of eggs and defibrinated blood.

For further details concerning the life-history of this spirochæte, the reader is referred to the section on African Relapsing Fever in Chapter XXV., p. 708.

Spirochæta rossii Nuttall 1908.

This spirochæte can only be distinguished from *S. duttoni* by its biological reactions. It is the cause of East African relapsing fever, and is conveyed by *Ornithodoros moubata.*

Spirochæta novyi Schellach 1907.

In 1907 Professor Manteufel, while investigating an accidental laboratory infection of relapsing fever, found that the serum of the patient agglutinated a spirochæte found by Novy in a case of relapsing fever in America in a dilution of 1 in 100, but showed no such power over the spirochæte of the European disease.

Moreover, it gave Pfeiffer's reaction, being active in doses of 0·05 c.c. in experimentally infected mice. Schellach has investigated this spirochæte, and given it the specific name used above. He finds it is 17 to 20 μ in length, with six to eight undulations, and a thickness of 0·31 μ. He gives the dimensions for the *S. recurrentis* as 19 to 29 μ, with eight to ten undulations and a thickness of 0·39 μ, and *S. duttoni* as 24 μ at the most, with eight to ten undulations, and a thickness of 0·45 μ; which appear to be very different from Novy's table given under *S. carteri.*

The spirochæte appears to have great flexibility and activity of movement. One end has a filiform prolongation about 5 μ in length, while the other is merely pointed. No undulating membrane could be differentiated; but he states that he was able to demonstrate lateral cilia, which he considers to be artificial; but this, in our opinion, is highly suggestive of the presence of an undulating membrane. Coloured granules could be made out when stained by Giemsa. Reproduction was usually by transverse division.

The spirochætes are found in the blood during the attacks of fever, and equally distributed in the organs in the apyrexial interval.

Spirochæta carteri Manson 1907.

S. carteri has not yet been sufficiently studied, but it is apparently thinner than *S. novyi*, and it is not agglutinated by serum of animals immunized against *S. novyi.*

Novy and Knapp give the following differences between *S. carteri*, *S. duttoni*, and *S. novyi* :

Character.	*Spirochæta novyi.*	*Spirochæta duttoni.*	*Spirochæta carteri.*
Length of simple cell ..	8 μ	16 μ	8 μ
Length of double cell ..	16–20 μ	30 μ	16–20 μ
Width	0·25 μ	0·2 μ	0·2 μ
Number of turns in a single cell	2·3 μ	2·5 μ	2–3 μ
Distance between the turns	1·5 μ	4·5 μ	2·3 μ
Movement	Vigorous	Little	—
Number in peripheral blood	Many	Few	Many

They can also be distinguished by agglutination, immunization tests, by Pfeiffer's reaction, and by certain animals being susceptible to some species and not to others. Mackie has suggested that *Spirochæta carteri* may be transmitted by a pediculus.*

Spirochæta schaudinni Prowazek 1907.

This is a very active motile spirochæte 10 to 20 μ in length, with a well-marked undulating membrane and one rather short flagellum. Male and female forms can be seen, according to Prowazek. Division is longitudinal. It is, according to Prowazek, the cause of ulcus tropicum, and is possibly transmitted by a leech.

Spirochæta vincenti R. Blanchard.

This spirochæte is 12 to 25 μ in length, tapering at both ends, and possessing comparatively few elongated spirals.

It is often associated with the so-called fusiform bacilli, and is considered to be the cause of *Angina Vincenti*. Some authors believe that the same spirochæte is found in hospital phagedæna, in noma, and in ulcus tropicum.

Spirochæta aboriginalis Cleland 1909.

This spirochæte was found by Wise in British Guiana in 1906, and by Cleland in West Australia in 1909 in cases of granuloma inguinale. Its length is 6 to 18 μ, and it possesses but few coils which vary in depth. The extremities, according to Cleland, are blunt. Similar spirochætes have been found by Wise and others in a peculiar granulomatous affection, which attacks the genital organs of dogs and bitches.

Spirochæta bronchialis Castellani 1907.

This parasite was found by Castellani in cases of bronchitis in Ceylon. The name probably includes several varieties of spirochætes. The commonest form is 7 to 15 μ in length, and delicate in appearance, and shows a variable number of coils, and often tapers at both ends.

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* According to Strong's experiments, rats immunized against *S. recurrentis* and *S. novyi* are immune to *S. carteri*. He therefore believes these three strains to be closely allied, if not identical.

Thick and extremely delicate forms can also be seen.

Spirochæta balbianii Certés 1882.

This spirochæte is found in the crystalline style of oysters. The oysters are apparently affected; at all events, they are poorly developed. It has a well-defined, undulating membrane, strengthened by myonemes, and also a diffuse nucleus of rodlets of chromatin on an achromatic spiral, as has already been described.

Spirochæta anodontæ Keysselitz 1906.

S. anodontæ was found in the crystalline style of *Anodonta mutabilis* by Keysselitz in 1906, and in that of *A. cygnea* by Fantham in 1908.

It is 40 μ in length by 0·7 μ in breadth, with pointed ends and a spirally wound undulating membrane. The nucleus is diffuse, consisting of chromatin rodlets on a more faintly staining spiral.

Spirochæta anserina Saccharoff 1891.

Found in enormous numbers in the blood of geese in the Caucasus and Tunis. It causes fever, diarrhœa, tenderness of the feet, and death in about a week, the mortality being 80 per cent. It can be inoculated into other geese.

Spirochæta marchouxi Nuttall 1904.

Synonym.—*Spirochæta gallinarum* R. Blanchard 1905.

This spirochæte, which has been discovered by Marchoux, Salimbeni and studied by Balfour, is about 10 to 20 μ in length, causes disease in fowls in many countries—*e.g.*, Brazil, the Sudan, Egypt, and Tunisia. The symptoms are fever, diarrhœa, anæmia, somnolence, convulsions, and death in four to five days, or in chronic cases cachæxia and death in fourteen days. As first observed by Sambon, it appears to enter the red corpuscle, and to break up within it in a way which reminds one of the description already given for *S. duttoni*. It is spread by *Argas persicus* and other Argasidæ, as Fülleborn has shown with *Ornithodoros moubata*. Balfour has made the important observation that in the infected ticks chromatin granules are present as described by Leishman in *S. duttoni*.

Spirochæta neveuxii Brumpt 1909.

Brumpt describes this spirochæte as morphologically identical with *S. marchouxi*, but cross immunization shows that the two species are different. It is the cause of fowl spirochætosis in Senegal, and is spread by *Argas persicus*.

Spirochæta theileri Laveran 1904.

This spirochæte, discovered by Theiler in 1902, is found in cattle in Africa about Pretoria, in the Cameroons, and in East Africa. The symptoms are not clear, as babesia has also been seen in the same animals. It is spread by *Margaropus decoloratus*, the blue tick.

Spirochæta ovina R. Blanchard 1906.

This spirochæte may be the same as *S. theileri*. It was found by Martoglio nd Carpano in sheep at Erythræa, on the Red Sea, and by Theiler in the Transvaal.

Spirochæta equi Novy and Knapp 1906.

Found by Theiler in the Transvaal, and by Martin in French Guinea, and may be the same as *S. theileri*.

Other Spirochætes.—*S. vespertilionis* Novy and Knapp, found by Nicolle nd Contine in 1905, in *Vespertilio kuhli*.

S. hachaizæ Kowalski, found in cholera motions.

S. culicis Jaffé, found in the gut and Malpighian tubules of *Culex pipiens* and the larva of *Anopheles maculipennis*.

S. dentium Miller, in the human mouth.

S. muris Wenyon and *S. laverani* Breinl and Kinghorn, in mice.

S. refringens Schaudinn, associated with *Treponema pallidum* in syphilis.

S. acuminata Castellani and *S. obtusa* Castellani, in the open sores of yaws.

S. bufonis Dobell 1908, found in the rectum of a frog.

S. plicitalis Ehrenberg 1833, found in pond-water.

S. glossinæ Novy and Knapp 1906, in the stomach of tsetse-flies.

S. macaci Castellani and Chalmers 1908, found by us in monkeys in Ceylon in 1906. Somewhat similar spirochætes have been found by Leishman and Balfour in other species of monkeys.

S. microgyrata Gaylord and Calkins 1907, in cancer of the breast in mice.

S. balanitidis Hoffmann and Prowazek 1906, found by Hoffmann and Prowazek in balanitis.

S. lutræ Prowazek 1907, found by Prowazek in the otter.

Other spirochætes not as yet determined have been found in dysentery (Le Dantec, Toussaint, Simonin), in suppurative conditions (Mutzer), in the bone-marrow in a case of profound anæmia (Moritz). Recently Sambon has found spirochætes in scrapings from gastric ulcers in a fox.

Various spirochætes have also been observed in the stomach of normal cats, dogs, and rats (Bizzozzero, Salomon), in the intestinal ulcers of dogs and monkeys affected with trypanosomiasis (Balfour), in the intestine of normal mice (Wenyon) and birds (Kent).

Treponemidæ Schaudinn 1905.

Definition.—Spirochætacea with a minute thread-like body twisted into numerous fine coils, with pointed tapering extremities. The body is cylindrical on section, and not flattened, and the spirals appear preformed. There is no undulating membrane.

Classification.—Only one genus and three species.

Treponema pallidum Schaudinn 1905.

Synonyms.—*Spirochæta pallida* Schaudinn 1905, *Spironema pallidum* Vuillemin 1905, *Microspironema pallidum* Stiles and Pfander 1905, *Trypanosoma luis* Krzysztalowicz and Siedlecki 1905.

This treponema was discovered by Schaudinn in syphilis in 1905. It varies from 4 μ to 10 μ in length, average 7 μ, with a width up to 0·5 μ. It is twisted into spirals, which vary from six to twelve and more in number, the average being eight to ten, and are to a certain extent preformed—*i.e.*, not due to the parasite's movements. It moves by rotation on a long axis by gliding movements, forwards and backwards, and also by flexion of the whole body. The periplast is continued as long delicate processes at each end, which are considered by some to be flagella.

Krzysztalowicz and Siedlecki say that not far from the middle, the body may be nearly straight, and a clear spot can be observed, which they think is a nucleus ; but it might correspond to the similar area in *S. duttoni*. They also describe male and female gametes and conjugation, which they think leads to the formation of a cyst or spore, which may be carried viâ the blood-stream to different parts of the body, and there develop into treponemata.

The parasite is found in the primary sores and in the secondary lesions, but is very difficult to detect in tertiary eruptions, though it is abundantly present in the liver, spleen, decidua, the placental villi, the umbilical cord of syphilitic fœtuses and infants.

It is distinguished from other spirochætes (*S. refringens*) which may be met with on ulcerated surfaces by difficulty in staining; number, character, and permanence of the spirals; the terminal prolongations; absence of an undulating membrane; minute size, and delicacy.

Syphilis can be inoculated into chimpanzees and many other monkeys, and *T. pallidum* can be found in the lesions so caused, the incubation being fifteen to forty-nine days, average thirty days, for the primary eruption; and nineteen to sixty-one days, average thirty-three days, for the secondary eruption after the primary have appeared. In the lower monkeys the lesion remains localized to the seat of the inoculation.

Schereschewsky has cultivated, with a certain degree of success, *T. pallidum* on a medium of horse serum, brought to a gelatinous consistence by heating to 60° C., and partly autolyzed by keeping in an incubator at 37° C. for three days.

Treponema pertenue Castellani 1905.

Synonyms.—*Spirochæta pertenuis* Castellani June 1905, *Spirochæta pallidula* Castellani November 1905.

It is found in the scrapings taken from yaws papules, and is extremely fine and delicate, varying in length from a few microns to 18 μ to 20 μ, and possessing numerous uniform small spirals. The extremities are often pointed, but may be blunt or loop-like. Two treponemata may be found attached end to end or twisted one on the other, so that they are attached at only one end. A few chromatin dots can be seen in individuals. No undulating membrane has been observed.

Monkeys can be successfully inoculated with yaws, and in the lesions caused thereby *T. pertenue* is easily found. Monkeys immunized against yaws do not become thereby immune against syphilis, and *vice versâ*.

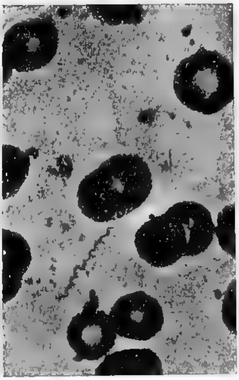

FIG. 101.—TREPONEMA PERTENUE CASTELLANI.

Treponema Sp. (?) Dobell 1908.

A rather doubtful treponema has recently been described by Dobell in the intestine of *Bufo vulgaris* L.

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CHAPTER XIII

BIOLOGICAL CAUSES OF DISEASE (*continued*)
PROTOZOA (*continued*)

Telosporidia—Gregarinida—Coccidiidea — Hæmogregarinida — Neosporidia—Myxosporidia—Actinomyxidia—Sarcosporidia—Haplosporidia—Heterokaryota—Ciliata—Holotricha—Heterotricha—References.

PHYLUM III. TELOSPORIDIA.

Definition.—Parasitic plasmodromata without motile organs, in which the reproductive phase of the life-cycle, which produces spores, is distinct from and follows after the trophic phase.

This phylum is considered by many authorities as being closely related to the Mastigophora.

All the Telosporidia are parasitic, and usually begin their life-cycle as small amœboid bodies, with a single nucleus, called trophozoites, which absorb nutriment and grow, and when fully developed show a cuticle, an ectoplasm, and an endoplasm. The ectoplasm frequently has contractile fibrillæ called myonemes. The endoplasm is granular, and contains a vesicular nucleus with chromatin karyosomes. The fully-grown trophozoite now begins to divide, and is known as a schizont, which reproduces by spore-formation. These spores, called merozoites, complete the cycle of asexual reproduction called schizogony. At some stage in the life-history of the parasite, generally when conditions of life are not favourable, some merozoites are produced, which, instead of developing into trophozoites, become sexual gametocytes, male and female. These forms, which are often resistant, are the means of transmitting the given species from one host to another. They produce gametes, which conjugate and form bodies called sporoblasts, and, lastly, spores called sporozoites.

The Telosporidia are divided into three orders: Gregarinida, Coccidiidea, Hæmogregarinida.

ORDER I. GREGARINIDA.

Definition.—Telosporidia, in which only the young trophozoites are intracellular, the fully-grown forms being extracellular.

Reproduction by Schizogony or Sporogony.—The gregarines are essentially parasites of the invertebrata, not being found in true vertebrates, though

nown in Amphioxus and Ascidians. They are generally found in the Arthro-
oda and worms, and appear to be non-pathogenic.

Their life-history may be briefly described as follows : The young tropho-
oite enters a cell, generally of the alimentary canal, in which it grows, appar-
ntly causing considerable damage, for the cell first swells and afterwards
egenerates.

In the meanwhile the parasite has found its way either wholly or partially
ut of the cell, to the remains of which, however, it is attached until all
ourishment is extracted, when it becomes cœlozoic—*i.e.*, it leaves the remains
f the cell, and dwells either in the alimentary canal, the cœlome, or the
lood-stream. The young parasite is unicellular, having its cytoplasm divided
nto ectoplasm and endoplasm. The ectoplasm is hyaline, and when
lly developed has three layers : (1) external epicyte, (2) middle sarcocyte,
3) internal myocyte.

The last-named contains contractile fibrils called myonemes. The endo-
lasm is granular, and contains a well-developed vesicular nucleus. A uni-
ellular gregarine, such as this, belongs to the suborder Acephala, and is
lustrated by *Monocystis agilis* Stein, which is found in the vesiculæ seminales
f *Lumbricus terrestris*.

On the other hand, in such a gregarine as *Pyxinia frenzeli* Laveran and
esnil, a part of the sporozoite grows out from the cell, and into this external
ortion the nucleus travels. The portion left in the cell is known as the
epimerite,' while the external portion, growing considerably, is divided by a
eptum into a 'protomerite' near the cell, and a 'deutomerite' away from the cell.
The parasite in this condition is called a cephalont, and belongs to the sub-
rder Cephalina.

In due course the trophozoite, whether entirely or partially in the cell, is set
ee, either by bursting its way out, or by a separation between the epi- and pro-
omerite. The cell now degenerates, and the parasite may be called a sporont.
porogony takes place by two sporonts or gametocytes lying side by side
ecoming enclosed in a cyst with two walls—an external epicyst and internal
ndocyst.

The karyosomes of the nuclei of the gametocytes now break up into
hromidia, which collect to form the generative nucleus. This divides by
itosis to form a large number of nuclei, which, travelling to the surface and
rrounding themselves with cytoplasm, become detached as gametes, the rest
f the cell forming a *nucleus de reliquat* or residual mass. Thus, inside the cyst-
alls there are gametes from two separate parasites and two residual masses.

Gametes presumably from different individuals fuse and form a true zygote
ith a synkaryon. Each zygote represents a sporoblast, and each sporoblast
ecomes a single spore by the secretion of a chitinous cuticle and the contrac-
on of its protoplasm (called by Minchin the ' sporoplasm '). This sporoplasm
ivides by amitosis into eight sporozoites and a residual mass. During this
rocess the two residual masses of the original cyst disappear. The cyst now
ontains only the spores which used to be called pseudonavicellæ. These
ores are intended to convey infection to a new host, in the intestine of which
ey set free the sporozoites, which promptly attack either the cells of the
testine or some other organ, thus completing the cycle of sporogony.

Schizogony.—This is uncommon in the gregarines, being only found in the
chizogregarinidæ. It is typically seen in *Schizocystis*, in which the tropho-
oite grows into a schizont, whose nucleus divides into a large number of
aughter nuclei, round each of which a portion of cytoplasm gathers, forming
merozoite. This, escaping from the schizont, infects another cell, thus com-
leting the cycle of schizogony. Some of the merozoites may develop by
orogony.

Classification.—The gregarines are classified as follows :

SUBORDER I. SCHIZOGREGARINIDA.

Reproduction by schizogony and sporogony.

Genera.—*Schizocystis* Léger 1900, in the intestine of *Ceratopogon*.
Ophryocystis Schneider 1884, in the Malpighian tubules of beetles.

SUBORDER II. EUGREGARINIDA.

Reproduction as usual by sporogony. Schizogony very rare, if present at all, and only in the earliest cytozoic stages. The Eugregarinida are divided into two tribes.

TRIBE 1. ACEPHALINA Kölliker.

Synonym.—*Monocystidea* Stein. No epimerite and no septa.

Genera (eighteen described by Minchin).—*Monocystis* Stein 1848, parasitic in the vesiculæ seminales and body cavities of the Oligochætæ and Cyclopidæ; *Zygocystis* Stein 1848, in *Lumbricus agricola; Zygosoma* Labbé 1899; *Lankesteria* Mingazzini 1891, in *Ascidians.*

TRIBE 2. CEPHALINA Delage.

Synonym.—*Polycystidea* Stein. With epimerite, and with or without a septum in the body.

SUBTRIBE 1. GYMNOSPOREA Léger.—Cyst with naked sporozoites (gymnospores).

FAMILY 1. AGGREGATIDÆ Labbé—**Genus**: *Aggregata* Frenzel 1885.—Sporozoites grouped about residual masses.

FAMILY 2. POROSPORIDÆ Labbé.—Each sporoblast giving rise to numerous sporozoites grouped round a residual mass.

Genus.—*Porospora* Schneider 1875. *P. gigantea* in the lobster.

SUBTRIBE 2. ANGIOSPOREA.—Spores well developed.

FAMILY 1. GREGARINIDÆ.—Trophozoites with simple epimerites.

Genera.—*Gregarina* Dufour 1828. Epimerite conical or knobbed. Species found in cockroaches, earwigs, meal-worms, and in the intestines of other insects. *Gamocystis* in the cockroach; also *Eirmocystis, Hyalospora, Euspora, Sphærocystes, Cnemidospora, Stenophora.*

Other families are Didymophyidæ, Dactylophoridæ, Actinocephalidæ, Acanthosporidæ, Menosporidæ, Stylorhynchidæ, and Doliocystidæ.

ORDER II. COCCIDIIDEA.

Definition.—Telosporidia, parasitic, as a rule, in epithelial cells of vertebrates and invertebrates. Reproduction always by both schizogony and sporogony.

The Coccidiidea were recognized as long ago as 1839 by Hake, who did not know that they were animals, that discovery being made by Remak (1845); while Lieberkühn in 1854 showed that they were allied to Gregarines. Leuckart (1876) gave them the name Coccidium, while Schaudinn in 1900 first described a full and complete life-history of *Coccidium schubergi*, which will be taken as the type.

Coccidium schubergi Schaudinn 1900.

Coccidium schubergi begins its life-history in the intestinal cell of the centipede (*Lithobius forficatus* L.) by a sporozoite pressing its anterior end against an intestinal cell, and thus forcing a way into its interior.

Inside this cell it becomes the young trophozoite, an oval body which grows rapidly at the expense of the protoplasm of the cell, and in twenty-four hours attains its full size.

It is now called a schizont, because its nucleus divides into a number of daughter nuclei, which are formed into merozoites in the usual way. These merozoites, set free by the breaking up of the schizont, attack new intestinal cells, thus increasing the infection of the host.

This process cannot, of course, go on for any length of time, for a limit to he nutritive power of the host is reached in five days, when the parasite must ttempt to infect a new host, and this is done by sporogony.

Some merozoites now become differentiated into micro- and macrogametocytes. The former consist of finely granular cytoplasm, with little reserve material, while the latter are bean-shaped and have much food-material. The microgametocyte forms the microgametes by its nucleus becoming irregular, and forming fine achromatic paths through the cytoplasm to the periphery of the parasite, along which chromidia travel from the nucleus. At first, scattered evenly along the periphery, these chromidia gather into

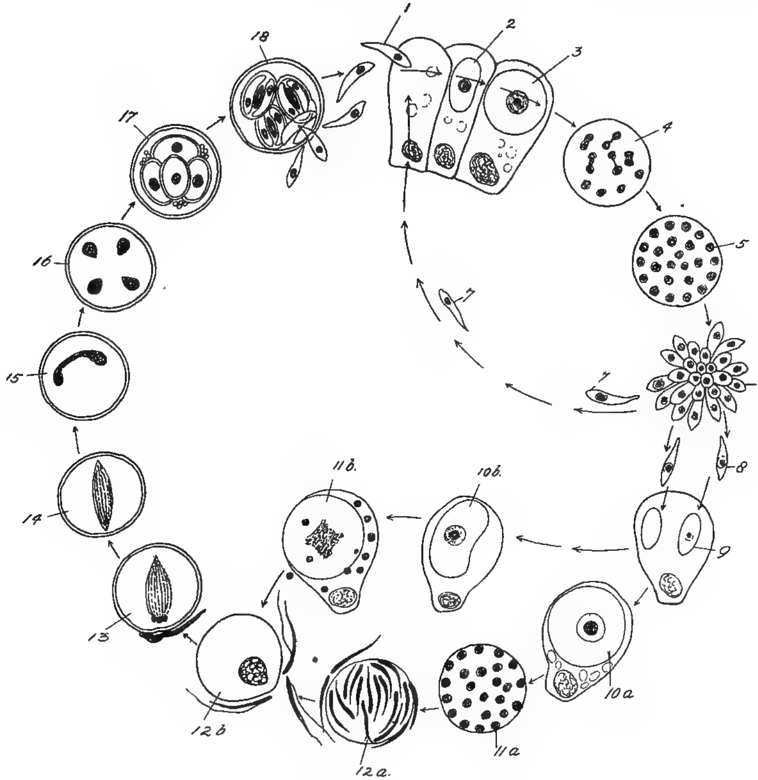

FIG. 102.—DIAGRAM OF THE LIFE-HISTORY OF COCCIDIUM SCHUBERGI. (After Schaudinn.)

1, Sporozoite entering an intestinal canal ; 2-3, trophozoites ; 4-5, schizonts ; 8, merozoites ; 9, young gametocyte ; 10*a*-11*a*, microgametocyte ; 10*b*-11*b*, acrogametocyte ; 12*a*, microgametes ; 12*b*, macrogamete ; 13-16, oöcyst ; , sporoblasts ; 18, sporozoites.

atches, and finally fuse into masses, enclosing in each a vacuole. The asses of chromatin lengthen, and by bending project from the cytoplasm, hich now forms two flagella, whose active movements set free the icrogamete.

In the meanwhile the macrogametocyte becomes a macrogamete by pulsion of the karyosome of the nucleus.

Micro- and macrogametes now fuse and form a zygote with a synkaryon.

The oöcyst, as it may be called, now passes out of the body of the host, and divides into four sporoblasts. Each sporoblast now develops two vacuoles and a cyst-wall, the sporocyst, so that the sporoblast is often called the spore. The nucleus of the spore divides into two, while the two vacuoles fuse and the cytoplasm divides, forming two sporozoites which are capable of infecting a new host, being set free by the acid of the digestive juices.

Sporogony takes about two to three days for completion.

It may be as well at the present time, when so much disputation is taking place *re* Schaudinn's work on trypanosomes, to mention that he worked out this life-history, which has never been refuted, though the parasite was found in company with *C. lacazei* Labbé and *Adelea ovata* H. Schneider.

Classification of the Coccidiidea.—The usual classification is that by Léger in 1900, and is based upon the number of sporozoites in each cyst.

Family 1. Asporocystidæ.—Sporozoites naked, no sporocysts inside the oöcyst.

Family 2. Disporocystidæ.—Oöcyst has two spores.

Family 3. Tetrasporocystidæ.—Oöcyst has four spores.

Family 4. Polysporocystidæ.—Oöcyst has many spores.

Family Asporocystidæ Léger.

The genus included in this family is *Eimeriella* Stiles 1902, of which there s only one species. *Eimeriella nova* Schneider 1881 in the Malpighian tubules of Glomeris.

Family Disporocystidæ Léger.

The genera of this family are : *Cyclospora* A. Schneider 1881 (spores dizoic) *Diplospora* Labbé 1893 (spores tetrazoic) ; *Isospora* A. Schneider 1881 (spores polyzoic).

Isospora A. Schneider 1881.

Isospora bigeminum Stiles 1891.

Synonym.—*Cytospermium villorum intestinalium canis et felis* Rivolta 1874.

This parasite lives in the intestinal villi of dogs and cats, and is distinguished because it is small and because it is in pairs, the oöcyst dividing into two equal portions, which become encysted and form two spores.

It is said by Virchow to occur in man, and Railliet and Lucet's case of *E. hominis* and the case described by Grünow are thought by Braun to be examples of this infection.

Family Tetrasporocystidæ Léger 1900.

Genus.—*Eimeria* A. Schneider 1874.

Synonym.—*Coccidium* Leuckart 1879 (the dizoic spores are spherical or oval) ; *Crystallospora* Labbé 1896 (the dizoic spores have the form of a double pyramid).

Family Polysporocystidæ Léger.

Comprises a large number of genera: *Adelea* A. Schneider 1875 (dizoic) ; *Klossia* (tetrazoic) A. Schneider 1875 ; *Minchinia* Labbé 1896 ; *Klossiella* Smith and Johnstone 1902 ; *Barronsia* (monozoic) ; *Benedenia* (trizoic). Of all these genera we are only concerned with *Eimeria*.

Eimeria A. Schneider 1875.

Eimeria stiedæ Lindemann 1865.

Synonyms. — *Psorospermium cuniculi* Rivolta 1878, *Coccidium oviforme* Leuckart 1879, *C. perforans* Leuckart, *Pfeifferia princeps* Labbé 1896.

This is the common species found in the liver of rabbits. The spores swallowed by the rabbit are opened by the action of the acid of the gastric juice, and the sporozoites set free ascend the bile-duct, and pass into the cells ing the small bile-ducts. Here they propagate vigorously by schizogony, using proliferation of the epithelium and connective tissue of the ducts, so at thick-walled nodules, more or less isolated and containing caseous material onsisting of detritus, pus, epithelial cells, and coccidia) are formed. The flammation may be severe enough to kill the rabbit.

Sporogony proceeds with the formation of macrogametocytes with macrometes, and the microgametocytes with microgametes, which conjugate and rm zygote, sporoblast, spores, and sporozoites.

Eimeria cuniculi has infected man in some five well-known cases : Silcock's se in London ; Gubler's case in Paris ; Dressler's case in Prague ; Sattler's se in Vienna ; and Perls' case in Giessen.

Silcock's case occurred in 1890, when the patient, a female aged fifty, ffered from fever, with enlarged liver and spleen, both of which contained ccidia, the infection of the spleen being probably viâ the blood-stream.

Eimeria hominis Rivolta 1878.

Synonyms.—*Coccidium hominis* Rivolta 1878, *C. perforans* Leuckart 1879.

This species is by many parasitologists considered to be the same as *imeria stiedæ*. It inhabits the intestinal cells of the rabbit, giving rise to evere diarrhœa and death. Moreover, its cysts are smaller than those of *stiedæ*, and more rounded ; further, it takes only two to three days r segmentation of the protoplasm of the cysts into sporoblasts, whereas *stiedæ* takes two weeks. It has been found in human fæces and in the ntestinal cells post mortem.

Under the same term R. Blanchard described certain bodies found by ünstler and Pitres in fluid from the chest of a man employed in working teamboats between Bordeaux and Senegal. Evidently R. Blanchard inended to describe a new species, as *Coccidium* was then the term used for the enus now called *Eimeria*.

ORDER III. HÆMOGREGARINIDA Neveu-Lemaire 1901.

Synonyms.—*Hæmosporidia* Labbé 1894, *Hæmosporea* Minchin 1903.

Definition.—Telosporidia, in which either the gametocytes or the schizonts, r both, are present in red or white cells in the peripheral blood of vertebrates, nd in which schizogony takes place either in the cells of the peripheral blood, r in those of some organ, while sporogony takes place in the body of some lood-sucking invertebrate, such as a leech, a ick, a mite, or an insect. Neither schizonts or sporonts contain hæmozoin.

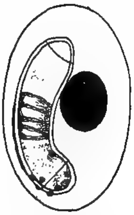

Fig. 103.—Hæmogregarina cantlei.

(After Sambon.)

Although the first hæmogregarine was disovered in a frog as far back as 1850 by haussat, who thought it was a nematode, it s only quite recently, owing to the labours of ambon, Miller, Miss Robertson, Christophers nd others, that any accurate knowledge has een obtained.

The evolution of the knowledge concerning hese parasites may be briefly stated.

Discovered, as mentioned above, by haussat, they were next seen by Ray ankester in 1871, and thought to be a stage n the life-history of the frog trypanosome, T. (*Undulina*) *rotatorum*, and then by Gaule in 1880, who mistook hem for cell inclusions. In 1885 Danilewsky first applied the name Hæmogregarina' to the parasites he found in the blood of tortoises and izards. In 1894 Labbé classified them, according to the relationship between he length of the parasite and that of the blood cell, into (1) *Drepanidium*, arasite not more than three-quarters of the length of the host cell ; (2) *Karyoysus*, parasite not exceeding host cell in length, and destroying the nucleus ;

(3) *Danilewskya*, parasite exceeding the host cell in length, and bent upon itself.

The term *Drepanidium* having been previously employed for one of the Heterokaryota, it was necessary to alter it to *Lankesterella*, and the term *Danilewskya* was also altered by Danilewsky in 1897 to 'Hæmogregarina' (*sensû strictû*); but since Sambon and others have described so many new species this classification no longer stands, nor can a natural arrangement be proposed, until the life-histories of the various species are fully known; therefore the suggestion of Laveran is being universally adopted, which consists of arranging them according to the classes, orders, and genera of the hosts, and distinguishing only one genus, *Hæmogregarina* Danilewsky 1885, the various species of which are arranged into four groups: (1) Hæmogregarinida of mammals; (2) Hæmogregarinida of reptiles; (3) Hæmogregarinida of amphibia; (4) Hæmogregarinida of fish. With regard to the Hæmogregarinida of mammals, they were first discovered by Bentley in the blood of a pariah dog (*Canis familiaris*) in Assam, and confirmed by James in 1905. In 1905 Balfour discovered *Hæmogregarinida jaculi* Balfour 1905 in *Jaculus gordoni* in Khartoum, and described the cycle of schizogony; but though numerous experiments were conducted with *Læmopsylla cleopatræ*, species of *Dermanyssus* (mites) and *Cimex macrocephalus*, only the liberated gametocytes have been traced. A danger is to mistake *Crithidia pulicis* of the flea for a developmental stage of the *H. jaculi*.

In 1905 Christophers discovered *H. gerbilli* in the Indian field-rat (*Gerbillus indicus*), and traced its schizogony and later cyst-formation in a louse (*Hæmatopinus stephensi*); but he did not observe conjugation, nor did he reinfect rats from the louse, and finally in 1907 he appears to think it probable that the cysts he described may have nothing to do with the hæmogregarine.

In 1906 Adie discovered a hæmogregarine in *Mus rattus*, Balfour one in *M. norvegicus*, Christophers another in *Felis domestica*, Patton another in *Funambulus pennantii*.

In 1907 Christophers traced the sporogony of *H. canis* in *Rhipicephalus sanguineus*. In 1908 Miller contributes a most valuable paper on *H. muris* Balfour 1905, under the term *Hepatozoon perniciosum* Miller 1908, in which he not merely traces out the cycle of schizogony, but also fully that of sporogony. This is the first description of the full life-history of a hæmogregarine ever given. This paper is also of the greatest importance in arranging the classification of the Hæmogregarinida, for, as already stated, Ray Lankester in 1871 believed that *H. minima* might be a stage of *Trypanosoma rotatorum*, and in this was supported by Billet in 1904, who considered that he could infect clean frogs with hæmogregarines by the bites of leeches containing trypanosomes.

Brumpt's experiments in 1904 on the sporogony of *H. bagensis* in the leech (*Placobdella catenigera*) also supports this theory by finding a binucleate condition in the oökinetes. Miss Robertson believes that hæmogregarines have a trypanosoma stage. These observers would therefore classify the Hæmogregarinida with the Binucleata; but against this Brumpt in 1907 has shown that Billet was probably mistaken, for if leeches infected with *T. inopinatum* are placed on a 'clean' frog a trypanosomiasis results, and the fact that though Sambon has often seen hæmogregarines in snakes and lizards, trypanosomes are absent or rare.

The life-history of *H. muris* as worked out by Miller shows no trypanosome stage, and clearly indicates that the Hæmogregarinida belong to the Telosporidia, and are related to the Gregarinida and Coccidiidea, as was pointed out by Laveran in 1898.

With regard to the Hæmogregarinida of reptiles, the most complete work s that of Sambon in 1908 on the parasites in snakes, where a full history will be found. Those which occur in tortoises and crocodiles have been studied by Danilewsky, Castellani and Willey, Miss Robertson and others, while Siegel has worked out fully the schizogony and sporogony of *H. stepanovi* n the leech.

The Hæmogregarinida of lizards have been studied by Danilewsky, Laveran, nchin, C. França, and others, and those of amphibia by Chaussat, Lankester, llet, Durham, Brumpt, Labbé, Lesage, and others.

Life-History.—The most accurately known life-history is that given for *muris* Balfour by Miller.

Schizogony.—The asexual reproduction takes place in the cells of the liver, which the young trophozoite appears as a small spherical organism with a ge vesicular nucleus containing a well-defined karyosome. The trophozoite ows at the expense of the liver cell, the nucleus of which is pushed to one le, and in due course becomes a schizont, which divides into twelve to twenty erozoites, and a 'rest' body.

Some of these merozoites on liberation enter fresh liver cells, and continue e cycle of schizogony, while others enter mononuclear leucocytes, in which ey become encysted, and develop into gametocytes.

Sporogony.—Sexual reproduction takes place in a mite belonging to the ımasidæ called *Lelaps echidninus* Berlese, which lives on the blood of the rat. The gametocytes, liberated from the leucocytes by the digestive action of e juices of the mite's gut, arrange themselves in couples, which are at first actly similar, but which later differentiate into a large encircling form, which more granular, and which is probably the macrogamete, and a smaller, ore rounded, and less granular microgamete. Zygosis now takes place, rming an oökinete, which grows, and leaving the gut by piercing the wall, ces its way into the body cavity, which consists of a series of small spaces tween the organs, and further into the sheaths of the muscles, and into the vesting membrane of the salivary glands.

In the tissues the oökinete encysts and becomes the oöcyst, which grows pidly in size, and undergoes nuclear division.

The daughter nuclei migrate to the periphery, which becomes covered with to 100 bud-like projections, in each of which a nucleus is to be ınd. These buds break off from the central mass, and form the sporo- ısts, the nuclei of which divide, forming daughter nuclei, which gather at the les, while the whole sporoblast encysts. Short rod-like processes of cytoplasm, ch containing a nucleus, now break off from the sporoblast, each of which be- mes a sporozoite, of which there are on an average sixteen to each sporoblast.

Infection of the rat takes place by ingestion of the mite, when the sporozoites liberated by the juices of the duodenum, and become actively motile iated vermicules, which penetrate the intestinal villi, enter the blood- eam, and are carried to the liver, into the cells of which they penetrate, and ırt the cycle of schizogony.

As the mites leave the rats during the day-time, and only feed on them during night, it is easy to understand the manner in which the disease spreads ım the sick to the healthy.

Variations in the Life-Cycle.—The life-history of *H. muris* is peculiarly eresting, because it is fully known, but it is not quite typical for all hæmo- garines, for in it the gametocytes alone found in the peripheral blood, and they enclosed in leucocytes.

Other species, however, show marked ferences from *H. muris*, for the majority found in red, not white, corpuscles, ile in some the whole process of ızogony is completed in the blood- eam, therefore a few more general remarks necessary to supplement the life-history en above.

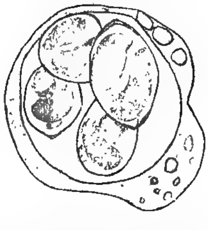

FIG. 104.—HÆMOGREGARINA VITTATÆ, SHOWING SCHIZOGONY. (After Miss Robertson.)

The peripheral blood of the vertebrate contain trophozoites, schizonts, and metocytes lying either in red or white puscles, the two latter being contained a double capsule, which is probably med by the parasite, and which is always in close attachment to the cleus of the host cell.

Schizogony begins with the young trophozoite lying free in the enclosing cell, as an oval, fusiform, or club-shaped mass of cytoplasm with a large, homogeneous nucleus. As this trophozoite grows it becomes encapsuled, and forms the schizont, which, when fully grown, is a large oval or rounded body, with a central nucleus, and with the cytoplasm filled with spherules. This schizont usually lies in an enlarged and dehæmoglobinized cell, in which it is seen to be surrounded by a thick capsule, which shows three definite cleavage lines, of which two cross it transversely a short distance from either pole, while the third is longitudinal.

There are two varieties of schizonts, one which gives rise to relatively few large merozoites called 'macromerozoites,' while the other breaks up into relatively many small micromerozoites.

This differentiation is considered to be a prelude to the formation of macro- and microgametocytes. Usually the schizont divides into eight, twelve, or sixteen merozoites, which may escape from the enclosing cell in the peripheral blood, but more generally do so in an organ, such as the liver, lung, or bone-marrow. Other hæmogregarines, like *H. jaculi* and *H. muris*, undergo segmentation in the cells of an organ such as the liver.

The gametocytes are easily recognizable from the schizonts, as they lie bent up in the capsule, and because the enclosing cell is not affected by the parasite. It is not possible at present to differentiate between the macro- and the microgametocyte.

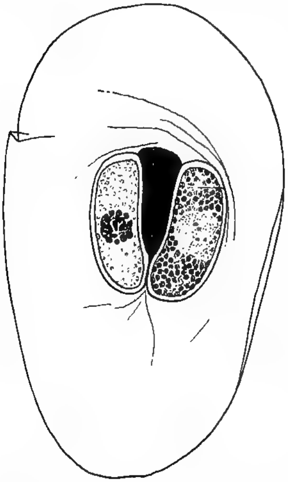

FIG. 105.—HÆMOGREGARINA RAREFACIENS, SHOWING MALE AND FEMALE SCHIZONTS.

(After Sambon.)

In shed blood they quickly escape from the capsule, which may be seen to be double, for Sambon depicts a gametocyte which has escaped from the outer wall of the capsule, but has the inner wall still adherent.

When free they are seen to be of an elongated, club-shaped form. At the thicker end, which is anterior, there projects a small retractile rostrum or beak, from which a clear line, probably a cytostome or pharynx, runs backwards through the cytoplasm, and ends near the nucleus.

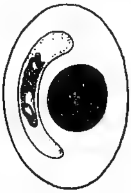

FIG. 106.—HÆMOGREGARINA RAREFACIENS: YOUNG GAMETOCYTE.

(After Sambon.)

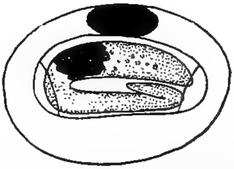

FIG. 107.—HÆMOGREGARINA SELIGMANNI, SHOWING CAPSULE AND CLEAVAGE LINES.

(After Sambon.)

The ectoplasm shows at times a differentiation into three layers—epicyte, sarcocyte, and myocyte—while the endoplasm is granular, and about its middle is found the round or oval nucleus.

According to Sambon, conjugation can be seen taking place in blood spread on an ordinary slide. The further history of the cycle of sporogony is only known in *H. muris* and *H. canis*; the former has already been described, and the latter will be mentioned later.

No hæmogregarines are at present known in birds or in man, but some peculiar parasites have been seen by Castellani and Willey and others in the peripheral blood of man (p. 337); whether these will prove to be hæmogregarines, or whether they belong to some other order of the protozoa, remains to be seen.

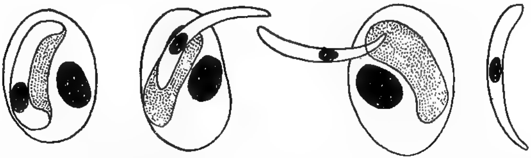

FIG. 108.—HÆMOGREGARINA MIRABILIS, SHOWING THE ESCAPE OF THE GAMETOCYTE FROM ITS CAPSULE.

(After Castellani and Willey.)

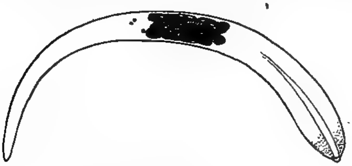

FIG. 109.—HÆMOGREGARINA SELIGMANNI: FREE SPORONT.

(After Sambon.)

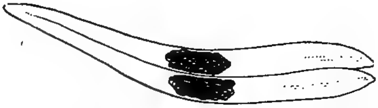

FIG. 110.—HÆMOGREGARINA SELIGMANNI.

According to Sambon, this figure probably represents conjugation.

(After Sambon.)

Classification.—As already mentioned, the species of the genus *Hæmogregarina* Danilewsky 1885 will be arranged according to their hosts.

HÆMOGREGARINES OF THE MAMMALIA.

Hæmogregarina muris Balfour 1905.

Synonyms.—*Leucocytozoon muris* Balfour 1905; *Hepatozoon perniciosum* Miller 1908.

H. muris is found in the mononuclear leucocytes of *Mus norvegicus* in Khartoum, and in white rats in Washington, D.C. Its schizogony and sporogony in *Lelaps echidninus* have already been described (p. 321). It caused anæmia, severe illness, and death in the rats.

Hæmogregarina canis James 1905.

Synonym.—*Leucocytozoon canis* James 1905.

Hæmogregarina canis was discovered by Bentley in the blood of a pariah dog, *Canis familiaris* in Assam, and this discovery was fully confirmed by James in 1905. Christophers was the first investigator to trace out its full life-history in 1906-07.

It appears to be common in pariah dogs in Assam and Madras, but more particularly in the puppies and less common in the adults. It is also found in Ceylon, and, according to Dutton, Todd, and Tobey it probably occurs in dogs in the Gambia.

Morphology.—The parasite is seen in the white corpuscle of the peripheral blood as an oval, unpigmented mass which is difficult to stain, and which lies in two envelopes—an outer formed from the cytoplasm of the corpuscle, and an inner formed by itself. The cell in which it lies is not typical of any corpuscle, though at first sight it resembles a polymorphonuclear leucocyte. When stained it is seen to possess a nucleus in the shape of a mass of chromatin stretching across the body at one end.

Schizogony.—Schizogony appears to take place only in the bone-marrow, and has not been seen in the liver or spleen. It begins by the parasite gathering itself on one side of the cyst-wall while the nucleus comes more into the middle. The cyst becomes more swollen and rounder, and is most difficult to stain, being brilliantly clear and refractile, but as it grows older it becomes filled with round or oval, clear, refractile granules of large size. No details are given of the action of the nucleus or of the cytoplasm during the stages, which, of course, marks a gap in the life-history. As the cyst matures the granules become less in number, and merozoites are seen lying among them, and, later, the granules having disappeared, only merozoites, which number about thirty, are seen lying, along with a little granular matter, in the oval or circular cyst, which may be 48 μ in diameter.

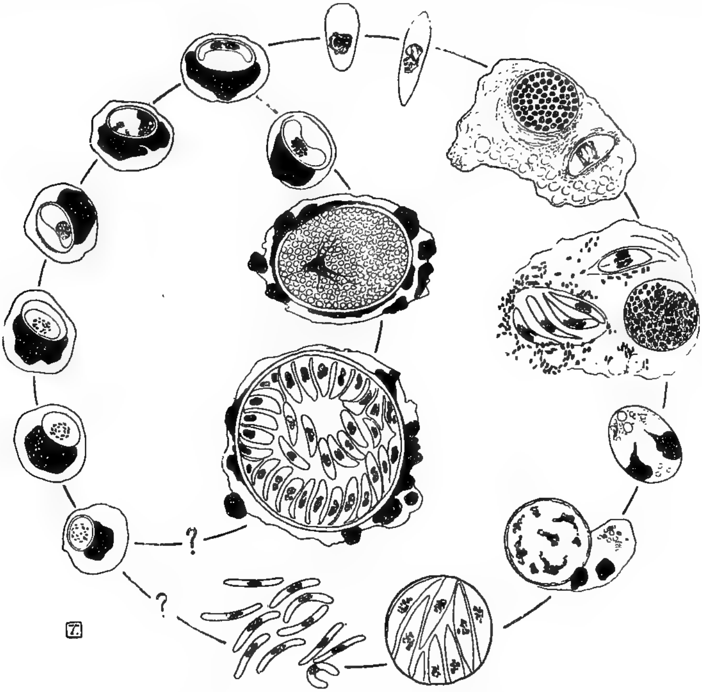

FIG. 111.—DIAGRAM OF THE LIFE-CYCLE OF HÆMOGREGARINA CANIS.
(Constructed from drawings by Christophers.)

It does not appear clear what happens to these merozoites, but from Christophers' description one is led to infer that they infect other cells in the bone-marrow of the dog, and thus become young trophozoites.

Trophozoite.—By inference one is led to believe that the trophozoite probably appears in the bone-marrow as a small, round, or egg-shaped body, possessing no capsule, and having a chromatin mass of isolated, rod-shaped granules arranged loosely in a circle. These trophozoites lie in a mononuclear cell, which are the parents of the transitional cells, which are looked upon as the parents of the polymorphonuclear leucocytes, but when infected by the parasite the proper development is not completed, and hence the appearance in the peripheral blood of a peculiar type of cell containing the encapsuled parasite. The young trophozoite is seen in the liver and spleen as well as in the bone-marrow, but is rare in the peripheral blood. This trophozoite grows into the encapsuled form just described, all stages between the two having been seen by Christophers, and in this way the cycle of schizogony is completed.

Sporogony.—The tick *Rhipicephalus sanguineus* Latreille is very common on the dogs in Madras. The female takes from two to four days to suck the blood, which it only does once in its lifetime, but most of the blood is taken in the last twenty-four hours. After sucking the blood it drops off, and when examined at different periods the following sporogony can be made out:

The encapsulated forms already described as existing in the blood pass into the stomach, and the parasite escapes from the corpuscle, but is still inside its own envelope.

By elongation and passage of the protoplasm behind the nucleus, the oval parasite becomes a vermicule. These vermicules must probably be looked upon as macrogametocytes and microgametocytes. In any case they enter young epithelial cells lining the lumen of the gut, in whose cytoplasm they divide by fission, which in many cases takes place several times, resulting in the secondary formation of four to eight vermicules lying in a pocket in the cytoplasm of the cell. Two of these secondary vermicules, which apparently, as a rule, do not differ in appearance, conjugate, and the nuclei fuse, and then follows a throwing out of two large masses of chromatin from the nucleus and the separation of a portion of cytoplasm. The former may represent reduction, and the latter the separation of the body cf the microgamete. Anyway, as the result of this process there is formed an oöcyst with a synkaryon, and therefore the conjugation results in a true zygosis. The oöcyst, still embedded in the epithelial cell, grows rapidly, and has a central clear area and outer rim of protoplasm, with chromatin diffused in irregular masses near the periphery. When about 14 μ in diameter, the oöcyst divides into twelve to fourteen sporozoites (or sporoblasts), which rather resemble vermicules, but differ by being more globular and having a short oval nucleus. These sporozoites escape into the lumen of the gut of the tick.

Whether these bodies are sporozoites or sporoblasts is not known; neither is it known how they get into the dog so as to complete the cycle of sporogony. In other words, there is a great gap in the cycle of sporogony at this point.

Hæmogregarina bovis Marfoglio and Carpano 1906.

In *Bos taurus* in Abyssinia. The parasites are 7 to 10 μ in length, and 1·5 to 2 μ in breadth, and possess rounded ends.

Hæmogregarina gerbilli Christophers 1905.

Found in the Indian field-rat, *Gerbillus indicus*, in which it produces only a little anæmia. It lies in cysts in enlarged pale blood-corpuscles as a vermicule with a bent tail, and has a median nucleus and some chromatin dots. In the louse *Hæmatopinus stephensi*, he describes the parasite as escaping from its cyst and becoming a free vermicule, which gets in the cœlome, and there encysts and becomes a large oöcyst, growing up to 350 μ in diameter. This oöcyst divides into numerous sporoblasts, which contain six to eight crescentic sporozoites. These, when free, appear as sausage-like bodies, 15 by 4 μ, with a distinct nucleus.

There is, however, some doubt as to whether these cysts are really developed from the hæmogregarine.

Hæmogregarina jaculi Balfour 1905.

Synonym.—*H. balfouri* Laveran 1905.

This parasite has been found in the jerboa (*Jaculus gordoni*) at Khartoum, and in *J. orientalis* in Tunis. It appears as a pale hyaline, homogeneous body, with the narrower end bent on itself, lying in a decolourized erythrocyte.

The trophozoite is found in a liver cell as an oblong parasite lying in a cavity. This body can divide into three young forms, which presumably can grow into schizonts in liver cells. The schizont divides into a large number of merozoites, leaving no residual mass of undivided cytoplasm. The merozoites probably infect the red blood cells, and after a time can escape into the liquor sanguinis as free trophozoites, and invade the liver cells.

What happens to the free vermicule is not known.

Hæmogregarina funambuli Patton 1906.

Synonym.—*Leucocytozoon funambuli* Patton 1906.

This parasite was found by Patton in the large mononuclear leucocytes of *Funambulus pennatii* (the Kathiawar palm-squirrel).

It is found in cysts in the leucocytes, and as free forms in the plasma. No evidence of schizogony could be found. In the gut of the louse (*Hæmatopinus sp.*) parasitic on these squirrels vermicules could be found, and also in the cœlome, but no further development took place.

Hæmogregarina ratti Addie 1906.

Synonym.—*H. ratti* Addie 1906.

This is a hæmogregarine found in the leucocytes of *Mus rattus.*

Hæmogregarina felis Christophers 1906.

Like *H. canis*, only found in cats. It was discovered by Patton. Schizogony and sporogony unknown.

HÆMOGREGARINES IN REPTILES.

Crocodiles.

H. hankini Simond 1901, in *Gavialis gangeticus* Gmel. ; *H. crocodilinorum* Börner 1901, in *Osteotæmus tetraspis* Cope, and in *C. cataphoractes* Cuv.

Hæmogregarines in the Chelonia.

A very large number of hæmogregarines are known in Chelonia, but the best-studied life-history is that of *H. stepanovi.*

Hæmogregarina stepanovi Danilewsky 1889.

H. stepanovi is a parasite in the red blood-corpuscles of tortoises—*e.g.*, *Emys orbicularis* L. and *Cistudo.*

It appears in two forms—one kidney-shaped, and the other long and thin and bent upon itself.

The young trophozoite is club-shaped, and grows into the broad kidney form, which in the bone-marrow, liver, or spleen breaks up into merozoites, which, escaping from the red cell, complete the cycle by entering new cells.

The trophozoite grows into a large oval form, which elongates until it gives rise to the long thin form which is bent upon itself. If blood containing this form is sucked by a leech (*Placobdella catenigera* Moqu Tand), it escapes from the corpuscle in the intestine, and, entering between the epithelial cells, develops into a macrogamete or a microgamete, and forms an oökinete, which wanders into the bloodvessels around the intestine, and so gets to the pharyngeal glands, in which it becomes an oöcyst forming numerous sporoblasts and sporozoites, which complete the cycle of sporogony by entering the tortoise when it is again bitten by the leech. There is also evidence of the infection of the ova of the leech in the finding of sporozoites in the pharyngeal glands of immature embryo leeches.

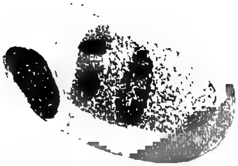

FIG. 112.—HÆMOGREGARINA VITTATÆ: A BROAD FORM, SHOWING PECULIAR RED BODIES.

(After Miss Robertson.)

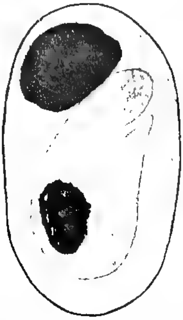

FIG. 113.—HÆMOGREGARINA VITTATÆ (GAMETOCYTE).

(After Miss Robertson.)

Hæmogregarina nicoriæ Castellani and Willey 1904.

This parasite is common in the tortoises (*Nicoria trijuga* Schweigg) which are found in the ditches and marshy lands round Colombo, and also in Colombo Lake. The young trophozoite grows into the schizont, which divides into merozoites.

Other parasites are *H. laverani* Simond 1901, in *Emyda granosa* Schoepff; *H. mesnili* Simond 1901, in *Kachuga tectum* Gray; *H. billeti* Simond 1901, in *Trionyx cartilagineus* Boddert; *H. stepanoviana* Laveran and Mesnil 1902, in *Damonia reevesii*; *H. rara* Laveran and Mesnil 1902, in *Damonia reevesii*; *H. mauretania* Sergent 1904, in *Testudo ibera* Pall.; *H. bagenesis* Ducloux 1904, in *Clemmys leprosa* Schweigg. Its sporogony is said to occur in *Placobdella catemnigera* Moqu Tand. *H. vittatæ* Robertson in Emyda vittata (Figs. 104, 112, and 113).

Hæmogregarines in the Ophidia.

The hæmogregarines of Ophidia are numerous, but their life-history has not been properly studied. They have mostly been described by Sambon.

Hæmogregarina mirabilis Castellani and Willey 1904 (Fig. 108).

H. mirabilis is a parasite in the red cells of *Tropidonotus piscator* Schn.

The trophozoite is vermicular and large (12 μ), and stains uniformly blue, leaving no clear pole. The nucleus is dense, and placed near the anterior end, and is enclosed in a well-developed cytocyst, which is stippled with Schüffner's dots.

Other forms are: *H. pythonis* Billet 1895, in *Python reticularis* Schn.; *H. pococki* Sambon and Seligmann 1907, in *P. molurus* L.; *H. schattocki* Sambon and Seligmann 1907, in *P. spilotes* Lacep.; *H. najæ* Laveran 1902, in *Naja tripudians* Merr; *H. mocassini* Laveran 1902, in *Ancistrodon piscivorus* Pal.; *H. crotali* Laveran 1901, in *Crotalus confluentis*; *H. seligmanni* Sambon 1907, in *Lachesis mutus*; *H. zamenis* Laveran 1902, in *Zamenis hippocrepis* L.; *H. mansoni* Sambon and Seligmann 1907, in *Zamenis flagelliformis* L.; *H. refringens* Sambon and Seligmann 1907, in *Pseudaspis cana* L.;

H. rarefaciens Sambon and Seligmann 1907, in *Coluber corais* Holb.; *H. cantliei* Sambon 1907, in *Eryx conicus*; *H. terzii* Sambon 1907, in boa-constrictor; and many others.

Hæmogregarines of the Sauria.

The best known of these is *H. lacertarum* Danilewsky 1885, in the red cells of *Lacerta muralis* Laur., *L. viridis* Laur., *L. agilis* L., and *L. ocellata* Daud.

The young trophozoite grows into a schizont, which is enclosed in a cytocyst, and which breaks up into merozoites in the liver, spleen, or kidney.

Among the merozoites there may be macromerozoites or micromerozoites, which are thought to be precursors of the macro- and microgametocytes which develop in *Ixodes ricinus* L. This tick may infect the lizard in the adult stage, though this must be rare, as it usually attacks mammals, and then only by its nymphæ and larvæ.

A number are described: *H. thomsoni* Minchin 1907, in the Himalaya lizard (*Agama tuberculata*); *H. schaudinni* C. França, in *Lacerta ocellata* Daud.

HÆMOGREGARINES OF AMPHIBIA.

The best studied of these is *Hæmogregarina minima* Chaussat.

Synonyms.—*Drepanidium ranarum* Lankester, *Laverania ranarum* Grassi, *H. ranarum* Kruse, *Lankestrella ranarum* Labbé.

This parasite is found in the red cells, leucocytes, and tissue cells of *Rana esculenta* L.

Schizogony takes place in the spleen, liver, kidney, and bone-marrow, where the cytocysts containing round schizonts, which break up into five to eight macromerozoites (5 to 8 μ) or numerous micromerozoites (3 to 4 μ).

The sporont is club-shaped, and sporogony takes place, according to Billet, in the leech (*Helobdella*), but his account is very doubtful and will require confirmation.

Hintze gives a quite different development in the intestine of the frog, but it is possible that he mistook a coccidial parasite for the sporogenic stages.

Durham notes a *Drepanidium* (hæmogregarine) in the blood of a toad in Para, and a *Dactylosoma* (Labbé) in the internal organs—the former is the schizont, and the latter the sporont—and found evidences of conjugation and cyst-formation in ticks fed on these toads.

H. splendens Labbé 1908 is found in *Rana esculenta* in Portugal. *H. leptodactyli* Lesage 1908 is found in *Leptodactylus ocellatus* in Argentina.

HÆMOGREGARINES OF FISH.

A short description of *H. simondi* will illustrate this class.

Hæmogregarina simondi Laveran and Mesnil 1901.

H. simondi is a parasite in *Solea vulgaris* (the sole). Schizogony takes place in the red corpuscles, the schizont dividing longitudinally into two, four, or eight merozoites. Sporogony takes place in *Platybdella soleæ* Kröger, a leech found on the sole in which oökinetes have been found.

Fish of all kinds and in all parts of the world appear to contain these parasites.

PHYLUM IV. NEOSPORIDIA.

Definition.—Parasitic plasmodromata, without motile organs, in which spore-formation and trophic growth proceed simultaneously.

The Neosporidia are protozoa in which reproduction and growth go on together. In the Telosporidia the trophozoite grows into the schizont which divides into spores; in the Neosporidia growth and spore-formation go on together ; but, as in the case of all attempts at classification, there are exceptions, for the trophozoite may grow into the schizont, and then divide.

It appears as though the Neosporidia were evolved from a sarcodinal ancestor.

They are divided into four orders : (1) Myxosporidia, (2) Actinomyxidia, (3) Sarcosporidia, (4) Haplosporidia ; and, in addition, there are a number of parasites belonging evidently to the protozoa, which cannot easily be classified, and are therefore placed in an addendum to the Neosporidia as *Protozoa incertæ sedis.*

ORDER I. MYXOSPORIDIA Bütschli.

Neosporidia with spore-formation commencing early in the amœboid trophozoite. Each spore has one or more polar capsules.

The Myxosporidia are subdivided into :

Suborder I. Phænocystes Gurley. **Synonym.**—Myxosporidia (*sensû strictû*). Spores with two to four large, clearly visible polar capsules.

Suborder II. Cryptocystes Gurley. **Synonym.**—Microsporidia (Balbiani). Spores with one minute polar capsule, which is only rendered visible by treatment with reagents.

SUBORDER I. PHÆNOCYSTES.

Phænocystes comprise the true Myxosporidia, being usually found in Teleostean fish, though they may occur in Elasmobranches, amphibia, and reptiles.

In fish they have long been known as psorosperms, being found in the bile-passages, the urinary organs, the muscles, and the nervous system.

The amœboid trophozoite has a differentiation of its cytoplasm into endo- and ectoplasm, and moves about by pseudopodia. Spore-formation begins early by a concentration of the cytoplasm around one of the nuclei of the trophozoite. This concentrated area is marked off by a capsule, and is the pansporoblast. The nucleus of the pansporoblast divides repeatedly, after which the cytoplasm splits into two masses—the sporoblasts—each of which s covered by a cuticle and contains three nuclei.

The cytoplasm of the sporoblast now divides into three areas around the nuclei. One of these areas is large, and is called the sporoplasm, while the other two are small, and form the polar capsules. Each spore, therefore, contains two polar capsules and one mass of sporoplasm, which represents a ingle sporozoite. Each polar capsule develops a spirally coiled thread. A pore escapes when the parent trophozoite dies, and then finds its way out of its host by the bile or urine, or through the tissues into the alimentary canal. For further development it must be swallowed by another host, in whose alimentary canal the threads of the polar capsules are extruded, fixing the little pore, which bursts and allows the amœboid sporozoite to escape and go on its travels in search of a suitable tissue. Perhaps *en route* it conjugates with another sporozoite ; if so, this is not known. While sporogony is preparing, chizogony may take place by plasmotomy, which is the division of the multinuclear trophozoite into two or more forms.

It will thus be seen that growth, plasmotomy (schizogony), and spore-ormation (sporogony) go on simultaneously.

Classification—Disporea Doflein.—Phænocystes with two spores.

FAMILY.—Ceratomyxidæ Thélohan.

Genera.—*Ceratomyxia, Leptotheca.*—Parasitic in fish and frogs.

Polysporea Doflein.—Phænocystes with more than two spores.

FAMILY 1.—Myxidiidæ Thélohan.

Genera.—*Sphærospora, Myxidium.*

FAMILY 2.—Chloromyxidæ Thélohan.

FAMILY 3.—Myxobolidæ Thélohan.

SUBORDER II. CRYPTOCYSTES.

This order is divided by Doflein and Perez into :—

Tribe 1. *Monosporogenea* Perez.—Trophozoite becomes a single pansporoblast (sporont), which produces a single spore.

Genus.—*Nosema* Nägeli.

Tribe 2. *Oligosporogenea* Doflein.—Trophozoite becomes a single pansporoblast (sporont), which produces four to eight spores.

Tribe 3. *Polysporogenea* Doflein.—Trophozoite becomes numerous pansporoblasts (sporont), which produce many spores.

Tribe 1. *Monosporogenea.*

This tribe includes *Nosema bombycis* Nägeli 1857, which is the cause of pébrine, the silkworm disease.

Tribe 2. *Oligosporogenea.*

This includes the genus *Gurleya* Doflein, *Thélohania* Henneguy, and *Pleistophora* Gurley.

Tribe 3. *Polysporogenea.*

This includes the genera of *Glugea* Thélohan, and *Myxocystes* Mrazek, of which *Glugea anomala* Moniez is a parasite of the stickleback.

Microsporidium polyedricum Bolle, a doubtful species, is said by Perroncito to occur in man.

ORDER II. ACTINOMYXIDIA.

These are parasites in the Tubificidæ of the oligochæte worms, and need not concern us.

ORDER III. SARCOSPORIDIA.

Definition.—Neosporidia in which the young trophozoite is, with rare exceptions, found in the muscle-fibre of warm-blooded animals. Spore-formation commences early, and proceeds during the whole growth of the trophozoite, which may attain a very large size, when it is covered by two coats, the inner of which is prolonged internally through the parasite dividing it into a series of chambers.

The Sarcosporidia, discovered by Miescher in 1843, are very common parasites, and in the form of *Sarcocystis tenella* may be seen by the practitioner in the tropics in meat sent as food to gaols and hospitals.

Two genera are known : (1) *Sarcocystis*, (2) *Rhinosporidium.*

1. **Sarcocystis** Lankester 1882.

Though a common parasite, its life-history is by no means well known. The youngest form is the trophozoite described by Bertram, which lies in a muscle-fibre, and consists of cytoplasm united by a cuticle, and containing several mononuclear pansporoblasts. The next stage is more advanced, for in this the trophozoite has grown considerably, and now consists of two coats—an outer, radially striated, and an inner, homogeneous, which is prolonged externally into filaments and internally into a series of septa, marking out chambers, each of which contains one pansporoblast. Internal to this coat is a layer of cytoplasm forming the endoplasm of the parasite.

The poles of the parasite consist of undifferentiated endoplasm, and form the areas of growth of the young trophozoite. The pansporoblast breaks up into a large number of spores.

The third stage is reached when the parasite has grown so much that it has stretched the muscle-fibre, in which it is lying, into a thin sheath covering it, and therefore now appears to lie between the muscle-fibres. The endoplasmic layer extends all round the interior of the parasite, so that the pansporoblasts are formed from the whole periphery, and therefore the youngest forms are in this position, while, farther in, chambers with the fully developed pansporoblasts are found, and, still farther in, is the centre of the parasite, filled by a granular substance formed from broken-down and dead spores which have been too long in existence.

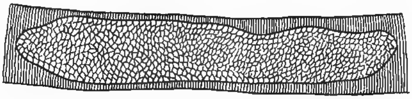

Fig. 114.—Sarcocystis tenellæ bubalis: Young Form.

As to the spores, a curious point to be noted is that some observers only describe gymnospores, while others only describe chlamydospores. Minchin suggests that this is because parasites in different stages of their life-history have been examined, and he looks upon the gymnospores as merozoites and the chlamydospores as spores, and these views are strongly supported by Korté's description of a form in *Macacus rhesus*.

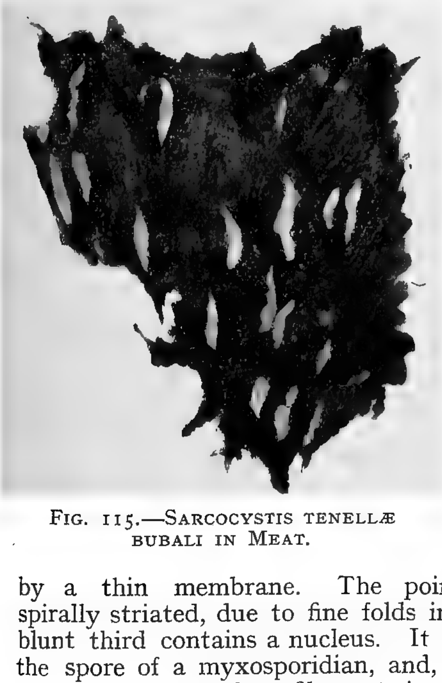

Fig. 115.—Sarcocystis tenellæ bubali in Meat.

The merozoites are crescent-shaped, naked spores, from 1 to 12 μ in length, according to the species, consisting of a finely granular protoplasm with a nucleus, some granules, and one or two vacuoles. They are thought to be the means by which the parasite spreads itself in its host, especially as they are motile by gliding, corkscrew, or amœboid movements.

The spores are from 3 to 14 μ long in *Sarcocystis tenella*, with one extremity rounded and the other pointed. They are curved, and surrounded by a thin membrane. The pointed third of the spore is spirally striated, due to fine folds in the outer capsule, while the blunt third contains a nucleus. It is obvious that this resembles the spore of a myxosporidian, and, in fact, Van Eecke says that one, two, or even three filaments issue from a spore.

It is thought that these spores spread the infection to another host, but in what manner is not clear. Perrin has recently suggested that the parasite may be transmitted by the larvæ and imagines of the blow-fly (Calliphora) or the flesh-fly (Sarcophaga).

It is true that Smith has infected (after a long incubation) mice by feeding them on the flesh of infected mice, but that, of course, might simply be by the merozoites, and would in any case not explain how herbivorous animals are infected. Our feeding experiments with a dog were not successful.

Sarcocystis tenella bubali is very common in the buffalo-meat in Ceylon, and frequently causes inquiries to be made. It appears as white particles, called by the native butchers ' milk-nerves,' lying among the muscular fibres of tongue, larynx, diaphragm, and skeletal muscles. This ingestion of infected meat has apparently no deleterous effect on man.

Classification.—Only one genus is recognized—viz., *Sarcocystis* Lankester 1882.

1. *Sarcocystis miescheriana* Kühn 1865, found in the pig.
2. *S. bertrami* Doflein 1901, in the horse.
3. *S. tenellæ* Railliet 1886, in the sheep.

S. tenellæ bubali, in the Ceylon buffalo. Vuillemin has described a case of this infection in man.

4. *S. blanchardi* Doflein 1901, in cattle.
5. *S. lindemanni* Rivolta 1878.—This species has been found in man. They were first described indefinitely by Lindemann in 1868 in the myocardium and on the valves of the heart of a person who had died of dropsy. They were said to be 3 millimetres in length and 1·5 millimetres in breadth, but it is very doubtful what these really were.

Rosenberg, in 1902, reports a most doubtful case of a cyst in a papillary muscle in a person who died from pleuritis and endocarditis. Kartulis described them in the muscular system and liver (most doubtful)of a person who died from multiple abscesses in the liver and muscles. The man was a Sudanese. Koch, in 1887, described an undoubted case in Egypt.

Baraban and St. Remy, in 1894, described them in the laryngeal muscles of a man who had been executed. This description is not to be doubted. The parasite is described as being 1·6 millimetres long, and about 0·17 millimetre in width.

6. *S. hueti* Blanchard 1885, in the seal.
7. *S. kortéi* Castellani and Chalmers 1909.—This parasite, found by Korté in the thigh muscles of *Macacus rhesus*, is peculiar in that the inner coat was not continued into the cytoplasm of the trophozoite, and the endoplasm contained only gymnospores (merozoites), and no pansporoblasts or alveolar network. The spores contained nothing but a nucleus, no cell membrane or other structure being visible. There were no signs of any reaction on the part of the tissues.
8. *S. aramidis* Splendore 1907.—Parasite in *Aramidis saracura*, a Brazilian bird.
9. *S. ammodromi* Splendore 1907.—*Miescheria ammodromi* Splendore 1907. Mesnil says it is not generic, and perhaps not specific. It is found in a Brazilian bird, *Ammodromus manimbe*.

2. Rhinosporidium Minchin and Fantham 1905.

Definition.—Sarcocystidæ with well-defined sporoblast.

Kinealy in 1903 reported to the Laryngological Society a peculiar case of polypus growing from the septum of the nose of an Indian

Calcutta as a pedunculated vascular growth resembling a rasp- rry in appearance by having whitish spots on the general red rface. On section, this tumour was found to have peculiar dies embedded in it.

It was then carefully examined and described by Minchin and ntham, who came to the conclusion that it was a haplosporidian, d named it *Rhinosporidium kinealyi.*

In 1905 Nair of Madras came across a similar polypus in several ople who all came from the small native State of Cochin on the est coast of India. These polypi have been carefully described Beattie in 1906.

On cutting into the polpyus it is noticed that there are minute ts visible to the naked eye, and capable of being dissected out. ese dots are cysts.

When examined with the microscope, it is seen that the growth covered by stratified pavement epithelium, which shows signs of oliferation and invasion by polymorphonuclear leucocytes. Under is epithelium there is a stroma formed of delicate fibrous tissue, yxomatous in places, and cellular at other spots. The cysts were und to be oval, round tubular, branched or irregular bodies, lying low the epithelium principally, but also found in hæmorrhages d in cell collections. The wall of the cyst is generally thin, and s either an opening or a conical elevation at one point. It consts of two layers—a thinner external and thicker internal coat. e smaller cysts, from 10 to 30 μ in diameter, contained undifferentiated protoplasm with a vesicular nucleus containing a nucleolus. e larger cysts had one or more definite chromatic masses. A lly developed cyst is lined with protoplasm, in which young pan- oroblasts are forming, while the centre of the parasite is full of d pansporoblasts, separated from one another by an indefinite mework continuous with the capsule. A young pansporoblast seen to be a small oval or rounded mass of cytoplasm with a gle nucleus. This body grows, and becomes surrounded by a embrane, while its nucleus divides by amitosis into four to sixteen ores, each of which has a very thin wall and a central nucleus. e pansporoblasts and spores are set free by rupture of the cyst, d may be surrounded by polymorphonuclear leucocytes, thus rming minute abscesses, or may be engulphed by mononuclear cocytes, or may grow into parasites, or escape from the host in e nasal secretion. The method of infection is not known.

The framework inside the cyst separating the pansporoblasts dicates that *Rhinosporidium* belongs to the Sarcosporidia, and t to the Haplosporidia.

The pathology appears to be a proliferation of the submucosa d mucosa of the nose, brought about by the irritation of the rasite.

Treatment.—Removal and cauterization.

ORDER IV. HAPLOSPORIDIA Caullery and Mesnil 1899.

Neosporidia with very simple life-history and undifferentiated cell-plasma, without septum and with spores of simple structure, with one nucleus, and no polar capsules.

The Haplosporidia are characterized by the simplicity of their life-cycle, which begins with a mononuclear or binuclear trophozoite, which may encyst, and in any case grows larger and larger, while its nucleus divides into several nuclei, so that a multinucleated mass or schizont is formed. This escapes from its cyst and divides up into merozoites, either directly or after plasmotomy, each of which becomes a trophozoite, thus completing schizogony. Sporogony is unknown.

They are parasites of fishes and invertebrates.

Classification.—FAMILY 1. HAPLOSPORIDIÆ Caullery and Mesnil.—Spores with double envelope and opening.

Genus 1. *Haplosporidium.*—Spores closed by a valve. In annelids.
Genus 2. *Urosporidium.*—Spores open. In annelids.
FAMILY 2. BERTRAMIIDÆ.—Spore envelope without opening.
Genus 1. *Bertramia.*—Stomach of fish.
Genus 2. *Ichthyosporidium.*—In tumours of fish.
FAMILY 3. CŒLOSPORIDIIDÆ.—Spores nude.
Genus 1. *Polagarynum.*
Genus 2. *Blastulidium.*

Protozoa Incertæ Sedis.

Cytoryctes Variolæ Guarnieri 1892.

Synonym.—*Strombodes jeuneri* Sjöbrung 1902.

In 1892 Guarnieri described peculiar parasitic bodies in lesions of smallpox, and in those produced by vaccination of the cornea of rabbits, etc. Pfeiffer, in 1893, confirmed these findings, as did Jackson Clarke in 1894, and Wasielewski in 1897. Councilman, Magrath, and Calkins, in 1903, published the full account of the life-history of the parasite, and their findings have been confirmed—in part, at least—by De Korté in 1905.

In its youngest form *Cytoryctes variolæ* is seen in the cells of the skin as a minute spherical homogeneous body, 0·7 μ in size. No differentiation into nucleus and cytoplasm is possible, as the organism appears to be all nucleus. The parasite grows to 3 μ, and then shows a vacuolization in the centre, with sometimes a central dot. The periphery next shows minute unstained dots, which, when they become larger, take on the green of a Borrel's stain. The red staining material is called by Calkins protogonoplasm.

The organism can now change its shape and throw out pseudopodia, and lives in a vacuole near the nucleus ; there is no ectoplasm or endoplasm, no vacuoles, but only chromatin granules of protogonoplasm.*

Auto-Infection.—In a large parasite (10 to 14 μ) the protogonoplasm is distributed through the body in minute spherical granules lying in a minute vesicle, forming granules from 0·7 to 1 μ in diameter, which are liberated by disintegration of the framework of the host cell, while the rest of the cytoplasm form a *nucleus de reliquat.*

Sexual Development.—The homogeneous granules or gemmules may start the cycle of cytoplasmic organisms again, or may become germ-cells in the nucleus. The gemmules reach the nucleus, but they now stain uniformly and become minute, clearly-defined, homogeneous bodies—female gametocytes. Sometimes they fail to reach the nucleus and remain in the cytoplasm, in which they can only partially develop. Within the nucleus Calkins thinks they form male and female gametocytes, homogeneous granules, or the gemmules become spherical, with central red masses, and later red masses at the periphery—the male gametes. No conjugation has been observed.

The zygote is an amœboid body lying in the nucleus, and staining deeply. This zygote becomes a pansporoblast and the mother-cell of the sporoblasts. The spore is very minute, and contains a vacuole ; it migrates, and may travel into nucleus and form secondary sporoblasts.

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* Volpino has described minute motile granules in the epithelial cells, which he considers to be the true parasites.

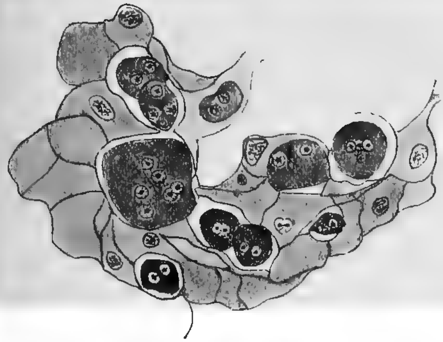

FIG. 116.—A SERIES OF SMALL ICHTHYOSPORIDIA ENCLOSED IN CONNECTIVE TISSUE.

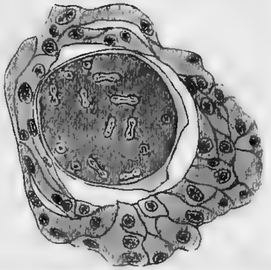

FIG. 117.—A MEDIUM-SIZED ICHTHYOSPORIDIUM IN A NEST OF CONNECTIVE TISSUE.

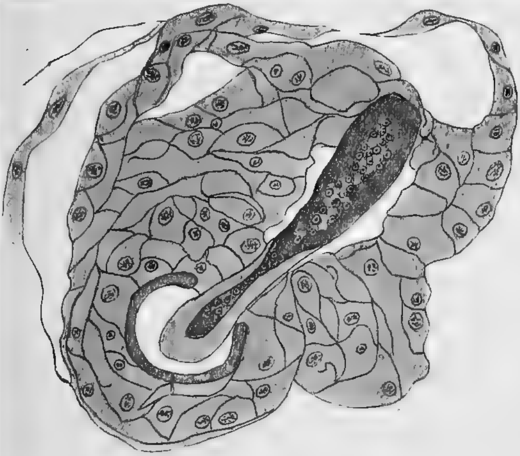

FIG. 118.—ESCAPE OF THE ICHTHYOSPORIDIUM FROM ITS CYST.

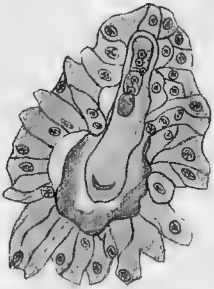

FIG. 119.—BREAKING-UP OF AN ICHTHYOSPORIDIUM INTO REPRODUCTIVE BODIES.

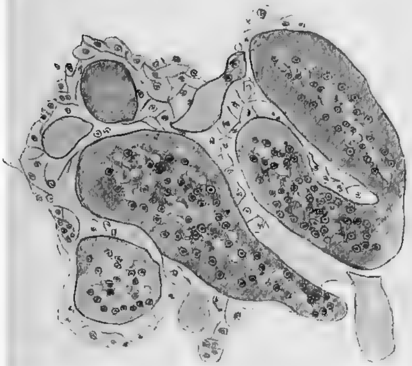

FIG. 120.—LARGE ICHTHYOSPORIDIA, ONE OF WHICH (ON THE RIGHT) IS UNDERGOING PLASMOTOMY.

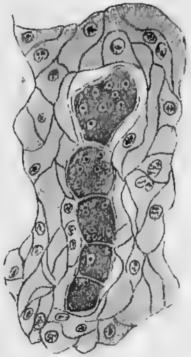

FIG. 121.—YOUNG FORMS DEVELOPED FROM THE BREAKING-UP OF A LARGE PARASITE.

(From drawings by Miss Robertson.)

Neuroryctes hydrophobiæ Calkins 1907.

Neuroryctes hydrophobiæ, better known as the Negri bodies, because they were discovered by Negri in 1903 as round or oval bodies, 1 to 23 μ in length, in the nerve cells of the brain, especially the *Cornu ammonis*, of animals suffering from hydrophobia, are now generally accepted as the cause of the disease. Hydrophobia is so common in India and Ceylon that a knowledge of its parasite is necessary to the practitioner in that part of the tropics.

Some authorities consider these bodies to be cell-structures, but in our opinion there cannot be any doubt that they are parasites, especially after the further investigation of Negri, amply confirmed by Williams, Lowden, and Calkins, who named it *Neuroryctes hydrophobiæ* Calkins 1907. Prowazek believes them to be Chlamydozoa, with which statement we are unable to agree. When stained by Giemsa the protoplasm takes on a bluish tinge like the malarial organism, while there is a central body like a nucleus, composed of a periphery of chromatin, and containing a central chromatic particle staining red. Negri, Williams, and Lowden give drawings indicating the rapid division and growth of the organism, which apparently as it grows divides, until finally large forms result whose chromatin breaks up into minute masses.

They consider that the parasite reaches the nervous system by spreading along the nerves, which it does more quickly than travelling by the blood.

Cyclasterella scarlatinalis Mallory (**Doubtful Species**).

In 1904 Mallory described round and elongated bodies, sharply stained with methylene blue, 2 to 7 μ in size, lying in the epithelium of the epidermis, together with radiate bodies, composed of a central spherical body with ten to eighteen segments radiating away from it, in epithelial cells and lymph-spaces of the epidermis of people suffering from scarlet fever.

This discovery has since been confirmed, both during life and in post-mortems, by Field and Duval.

Further research is needed before the nature of these bodies can be definitely settled.

Coccidioides immitis Rixford and Gilchrist 1897 (**Doubtful Species**).

Synonyms.—*C. pyogenes* Rixford and Gilchrist 1897, *Coccidium posades* Caxton (?) 1898.

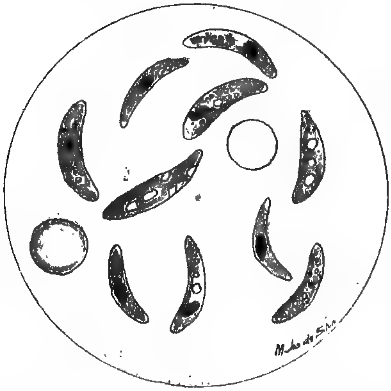

FIG. 122.—BODIES FOUND IN MAN BY CASTELLANI AND WILLEY.

These parasites were first seen by Wernicke and Possadas in Buenos Ayres, and later in the United States by Rixford and Gilchrist, Montgomery, Moffit, and Ophüls, where they cause an infection producing nodules in the skin, liver, kidney, genitalia, and lymphatic glands.

They are small, rounded bodies 3 to 30 μ in size, contained in giant cells.

The Bodies of Ureteritis Cystica (Doubtful).

In this disease the kidney is hydronephritic and the ureter and bladder are cystic.

The cysts contain large and small oval and irregular cells with bright globules, variously interpreted as Coccidia, Myxosporidia, and cell inclusions.

Bodies described in Man by Castellani and Willey.

These bodies were found and described in 1905 in two patients suffering rom irregular fever. They generally have a crescentic shape, 10 to 30 μ in ength, and 1·5 to 4 μ in breadth. They often present vacuoles, and a nucleus may be seen in some specimens, but not in all. The whole body stains bluish, while here and there granules of chromatin can be seen. They cannot be compared with malarial crescents, as they never contain pigment.

Bodies described in Man by the Brothers Sergent.

Et. and Ed. Sergent in 1908 reported a vermiform body, 40 μ long by 1 to 1·5 μ broad, pointed at each end, with a nucleus in the middle, in the blood of a person suffering from night-sweats and nausea.

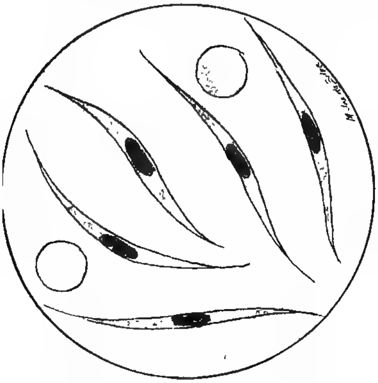

FIG. 123.—BODIES FOUND IN MAN BY THE BROTHERS SERGENT.

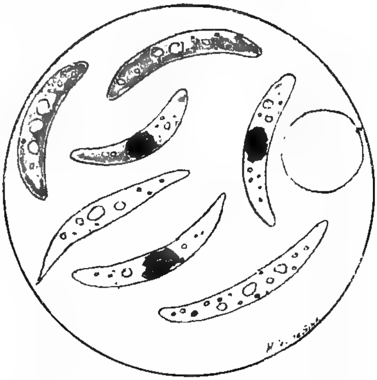

FIG. 124.—BODIES FOUND IN BOS INDICUS BY CASTELLANI AND STURGESS.

Bodies described by Castellani in Bos indicus.

These bodies were observed by Castellani in Indian bulls in 1906, and were considered by him to be closely related to those found in man. In preparaions stained by Giemsa the bodies have a bluish tint, with often specks of chromatin dotted here and there. The shape is crescentic, with acute or obtuse extremities; length, 10 to 30 μ; breadth, 3 to 5 μ. Very rarely fusiorm parasites may be seen. The protoplasm may be vacuolated, and in most individuals a central nucleus can be seen, which is large, and contains but little chromatin. Recently Castellani and Sturgess have observed another bullock with the same parasite.

Bodies found by Sambon in Pseudochirus peregrinus.

Recently Sambon has found bodies in a lemur which may have some relaionship to the above.

Bodies found by Neave in a Guinea-Fowl.

In 1906 Neave reported finding multinucleated bodies in *Numidia ptilorhyncha* (the guinea-fowl), but some authorities look upon these bodies as being possibly fungi.

The Chlamydozoa.

S. Prowazek considers that the endocellular bodies described as parasites f smallpox, hydrophobia, molluscum contagiosum, etc., are not the true paraitic agents of those diseases, but merely products of cellular reaction caused by the cells being invaded by minute germs appearing as delicate granules, olourable by various stains, but often Gram-negative. In presence of these minute germs the cells would react by a hyperproduction of nuclear and hromatic substances enveloping the granules. Prowazek considers the chlamydozoa to be more closely related to the protozoa than to the bacteria. He and Halberstadter have described chlamydozoa in trachoma, and recently Keysselitz and Mayer have described chlamydozoa in chicken-pox.

Histoplasma capsulatum Darling 1906.

Histoplasma capsulatum was discovered post mortem by Darling in Panama in 1906. It is a round or oval parasite, 1 to 4 μ in diameter, enclosed in an achromatic refractile capsule. It possesses a single nucleus, as a rule, and has chromatic spaces in the cytoplasm. It is found in the endothelial cells of capillaries and small bloodvessels, in the liver, spleen, lungs, intestines, and lymphatic glands, and also in leucocytes.

It causes a form of Splenomegaly which resembles Indian Kala-azar. The parasite differs from *Leishmania donovani* in possessing only a single chromatin mass. In smears from the lungs and spleen flagellate forms have been reported by Darling.

PHYLUM V. CILIATA Ehrenberg.

The Ciliata are free-living or parasitic Heterokaryota, found principally in water, where they exist upon small animal and vegetal organisms and the débris of decomposing plants and animals. Some of them can live in the alimentary canal of man and animals, obtaining their food from its contents, and increasing to such numbers as to cause irritation of the intestine.

Their movement is by cilia, but always with one end, the anterior, in front. They turn round when desiring to progress in a different direction. This anterior end may be similar morphologically to the posterior, or may be characterized by being more pointed, by having a mouth, or by peculiar sensory cilia (Hypotricha), or by a peristome of long cilia (Heterotricha). The body, which may be spherical or flattened, is divided into an ectoplasm (the cortex); and endoplasm (the medulla). The ectoplasm may simply be a clear outer layer of the protoplasm, or it may be differentiated into three layers. The first is very thick and very tough; the next, called the alveolar sheath, is marked by vertical parallel lines, which are the contractile myoneme threads; while the innermost layer next to the endoplasm consists of clear transparent ectoplasm.

The semi-fluid endoplasm is in constant rotatory motion, containing food vacuoles, contractile vacuoles, nuclei, pigment granules, colourless granules, crystalline bodies, and smaller particles. The cytostome or mouth is present in all except the parasitic Opalinæ. It is a slit in the cortex at the anterior end of the body, which can be opened for the reception of food, but is usually kept closed. It may be on the surface or may be carried inwards by a funnel-shaped depression in the ectoplasm called the vestibule, which may be lined by cilia specialized for the capture of food.

A cytopyge, or cell anus, occurs in *Nyctotherus*, but as a rule no definite opening appears, and the undigested food is simply pushed through the cortex.

Two wholly distinct nuclei exist in the Heterokaryota, a mega- or macronucleus and a micronucleus. They are not merely different in size, form, structure, and appearance, but also in function; for the macronucleus is somatic and trophic in its function, while the micronucleus is purely sexual. They are not comparable to the tropho- and kinetonuclei of the trypanosomes.

The macronucleus is generally well marked, but breaks down into granules before or after conjugation. It consists of an achromatic portion, with a chromatic portion in the form of a close-meshed network of fibrils, but whether there is a definite surrounding membrane or not is doubtful.

The micronucleus, when at rest, is a minute irregular granule of chromatin lying in the centre of a perfectly clear achromatic area. Probably there is only one in each animal, and the appearance of two or more is due to reproductive phases which are just finishing.

The Ciliata are characterized by the presence of protoplasmic processes projecting all over the body. These are fine, short whips, called cilia, which in places are transformed into thick processes called cirri or flat membranes in certain species. The cilia are processes of the pellicle, but they appear to be supported by a thread of specialized ectoplasm. The short, fine cilia are for motion, and the long, motionless cirri for the purpose of entangling food-particles. The membranes are supposed to be formed of fused cilia. Trichocysts exist in the Holotricha, and an excretory organ has recently been described by Metcalfe in certain species of Opalina, parasitic in frogs, while other Ciliata have a contractile vacuole.

Reproduction may take place asexually by (1) transverse or longitudinal division; (2) gemmation, simple or multiple; (3) encystment and spore-formation, or sexually by conjugation.

1. Fission.—There is no morphological distinction between longitudinal and transverse fission, in which the following changes take place: (1) A second mouth is formed; then comes (2) enlargement and division of the micronucleus; followed by (3) enlargement and division of the macronucleus; and, finally, (4) division of the cytoplasm.

2. Encystment and Spore-Formation.—The animal encysts and breaks up into a number of small individuals.

3. Conjugation.—Conjugation has been best described by Calkins and Caullery in *Paramœcium aurelia*. Two conjugating cells about the same size are placed so that the mouths are directly opposed. The micronucleus swells, its chromatin becomes granular, elongated, crescentic, fusiform, and finally forms two nuclei, each of which at once divides into two. Of these, two degenerate, while the other two divide to form a migratory, or male, and a stationary, or female, pronucleus. The male interchange and fuse with the opposite female nuclei, and then the organisms separate. The macronucleus fragments and disappears, and the synkaryon breaks up into eight micronuclei.

Four of these swell, and are changed into macronuclei; so that four micro- and four macronuclei are in the same cell, which divides into two very small cells with two macro- and micronuclei each.

These cells grow to nearly full size, and then divide, giving rise to the typical protozoon, with one macronucleus and one micronucleus.

Parasitism.—A great many species of the Ciliata are parasitic in the intestine or bladder of other animals, and some are epizoic.

The latter will often be met with as *Vorticellæ*, living on *Anopheles* and *Culex* larvæ. The former are found largely in the Orthoptera, the Amphibia, and in herbivorous mammals—*e.g.*, horse and cow.

In man a few have been recorded: *Chilodon dentatus* Dujardin 1842, *C. uncinatus*, *Colpoda cucullus* Schutz 1889, *Balantidium coli* Malmsten 1857, *B. minutum* Jakobi and Schaudinn 1898, *Nyctotherus faba* Jakobi and Schaudinn 1898, *N. giganteus* Krause 1906, *N. africana* Castellani 1905.

Parasitism does not appear to affect the structure of the animal, unless the loss of the cytostome in Opalina, parasitic in frogs, is considered to be due to this cause.

Pathogenesis.—The ciliate parasites, as a rule, appear to cause but little effect, unless they are present in large numbers, when diarrhœa, often severe and long-persisting, may result.

Classification.—The Ciliata are classified into four orders:

Order I. Holotricha.—Mobile Ciliata without special oral cirri (*Chilodon, Colpoda*).

Order II. Heterotricha.—Mobile Ciliata with special oral cirri (*Balantidium, Nycotherus*).

Order III. Hypotricha.—Mobile Ciliata with well-developed dorsal and ventral surfaces. Not known to be parasitic in man.

Order IV. Peritricha.—Fixed Ciliata. Not known to be parasitic in man.

ORDER I. HOLOTRICHA Stein.

The Holotricha are free-moving Ciliata, in which all the cilia are of approximately equal length and thickness, and never possessing cirri. It is divided into two suborders:

Gymnostomata.—Mouth closed when ingesting food.

Hymenostomata.—Mouth always open, and provided with an undulating membrane.

Gymnostomata.

FAMILY CHLAMYDODONTIDÆ Stein.—In this family there is a genus *Chilodon* Ehrenberg, which includes oval, strongly dorso-ventrally compressed Chlamydodontidæ, commonly found in infusions, of which one species, *C. dentatus* Dujardin 1842, was found in great abundance by Guiart in the motions of a woman suffering from severe dysentery in Paris. Quite recently Manson and Sambon have described a case of chance-parasitism due to another species, *C. uncinatus* Blochmann, in a patient from tropical South Africa. They noted that the parasites were only found in the mucus, never in the fæcal masses. They were present in very large numbers, and were found to be all gametes, some of which were conjugating. It appears probable that Guiart's parasites may really have been *C. uncinatus*, and not *C. dentatus*.

Hymenostomata.

FAMILY CHILIFERIDÆ Bütschli.—The genus *Colpoda* Müller includes the kidney-shaped Chilifera, with rows of cilia twisted from left to right, commonly found in hay infusions, of which one species, *Colpoda cucullus* Schutz 1899, commonly found in the water of marshes, was noticed in a brickmaker attacked with dysentery in Berlin.

ORDER II. HETEROTRICHA Stein.

The Heterotricha are free-moving Ciliata, with strong cirri or membranellæ, forming an adoral ring enclosing a space, the peristome, at one part of which the mouth opens. The order is divided into Polytricha, Oligotricha.

Polytricha.—Heterotricha in which the surface of the body is covered with rows of short cilia.

FAMILIES.—*Plagiostominidæ* Claparède and Lachmann, *Bursarinidæ* Bütschli, *Stentorinidæ* Stein, *Gyrocoryna* Stein.

Bursarinidæ Bütschli.

This family includes the genus *Balantidium*.

Balantidium Claparède and Lachmann.—Bursarina with a large peristome and a well-marked anal aperture.

Balantidium is common in the rectum of pigs, and is sometimes found in the intestines of man.

Balantidium coli Malmsten 1857.

Synonyms.—*Paramœcium coli* Malmsten 1857, *Balantidium coli* Stein 1867.

Balantidium coli is constantly found in pigs, and has been found in the colon and the dejecta of man in cases of cholera and diarrhœa.

In shape it is oval, slightly pointed anteriorly, but this depends upon whether the peristome is funnel-shaped or contracted. It is covered with cilia arranged in parallel rows, which give it a striated appearance.

It is 0·06 to 0·1 millimetre in length by 0·05 o 0·07 millimetre in breadth, and possesses a bean- or kidney-shaped macronucleus, and a globular micronucleus situated near it. It develops asexually by ransverse division or by conjugation. It can encyst, and in this

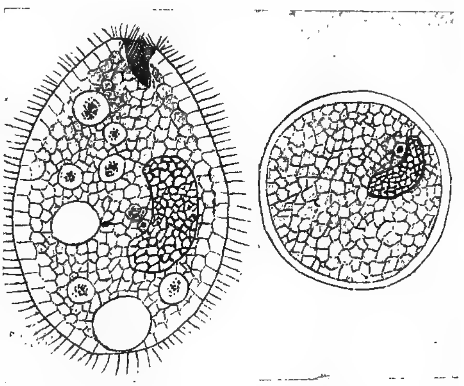

FIG. 125.—BALANTIDIUM COLI.
(After Hartmann. From the *Archiv für Schiffs- u. Tropenhygiene.*)

condition pass from pigs to man. *B. coli* lives in the rectum of pigs, and is transferred by its cysts to man.

It was discovered by Malmsten in a man who had had cholera, and was suffering from diarrhœa and ulcer of the rectum. The ulcer had nothing to do with the disease, as it healed, while the diarrhœa was probably due to the parasites.

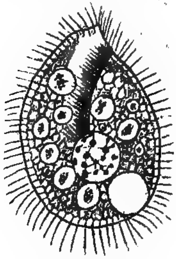

FIG. 126.—BALANTIDIUM MINUTUM.

After Hartmann. From the *Archiv für Schiffs- u. Tropenhygiene.*)

Casagrandi and Barbagallo produced catarrhal enterocolitis in young cats by means of this parasite.

Strong has investigated, in a masterly manner, the enterocolitis produced by *B. coli* in the Philippine Islands.

Balantidium minutum Schaudinn 1899.

The body is shortly oval, with a pointed anterior extremity. Length, 20 to 32 μ; breadth, 14 to 20 μ.

The peristome extends into the centre of the body, and has the right lateral border fringed with cilia, and the left lateral border terminates in a hyaline membrane which can pass over to the right side, and has a row of cirri. The cysts are oval.

This parasite (along with *Nyctotherus faba*) was found by Schaudinn in a German who had often stayed in North America. The symptoms were constipation alternating with diarrhœa associated with abdominal pain.

Nyctotherus Leidy 1849.

Body bean- or kidney-shaped, with a large peristome on the concave side extending from the anterior end up to the middle of the body, from where a curved cytopharynx or œsophagus extends inwards. The macronucleus is large, and situated almost in the centre.

The species are mostly parasitic in the intestine of Amphibia, Insecta, and Myriapoda.

Species known in man: *Nyctotherus faba* Schaudinn 1899, *N. giganteus* Krause 1906, *N. africanus Castellani* 1905.

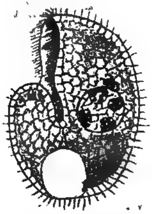

FIG. 127.—NYCTOTHERUS FABA.

(After Hartmann. From the *Archiv für Schiffs- u. Tropenhygiene.*)

Nyctotherus faba Schaudinn 1899.

N. faba is flattened dorso-ventrally, and is 26 to 28 μ in length, and 16 to 18 μ in breadth, and 12 μ in thickness. The cilia on the peristome are of two kinds, those on the right side, of the size of the body, being true cilia, and those on the left side being cirri. The contractile vacuole is large, and situated posteriorly. The macronucleus is in the centre, and is peculiar in having four or five large collections of chromatin at its periphery. The micronucleus lies close by. The cysts are oval.

This species was discovered by Schaudinn in the same patient as *Balantidium minutum*.

Nyctotherus giganteus P. Krause 1906.

Synonym.—*Balantidium giganteum* P. Krause 1906.

This organism, along with *Trichomonas intestinalis*, was found by Krause in the dejecta of persons suffering from typhoid in Breslau.

It is shaped like a truncated cone, with the anterior end narrowed, and the posterior broad. Length, 90 to 400 μ; breadth, 60 to 150 μ. Surface covered with cilia. The peristome is situated laterally, and from it a cytopharynx leads inwards.

The macronucleus is large and bean-shaped, while the micronucleus is small and round. One or two vacuoles can be seen. The cytopyge is situated posteriorly.

In the fæces the parasite becomes rounded off and encysted, and then divides into four.

Nyctotherus africanus Castellani 1905.

Found by Castellani in a Baganda native. *N. africanus* is hourglass-shaped, with the anterior portion much less developed than the posterior. Length, 40 to 50 μ; breadth, 30 to 40 μ. The surface partly covered with very minute and in some cases invisible cilia.

The peristome is short. The cytoplasm is finely granular throughout. The nucleus is situate far posteriorly, near the contractile vacuole. The micronucleus is very small, and situated close to the macronucleus. No food vacuoles are to be seen.

Neither division, conjugation, nor encystment are known.

The patient, who had diarrhœa alternately with long periods of constipation, was suffering from sleeping sickness.

The cæcum contained many parasites, as did other parts of the bowel. The mucosa of the cæcum, colon, and rectum were slightly congested but not ulcerated. Castellani originally considered this parasite to belong to the genus *Nyctotherus*, but more complete investigations will probably show that it constitutes a new genus.

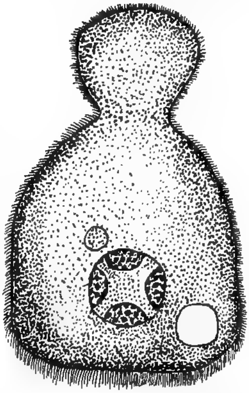

FIG. 128.—NYCTOTHERUS AFRICANUS CASTELLANI.

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CHAPTER XIV

BIOLOGICAL CAUSES OF DISEASE (*continued*) —TREMATODA

Metazoan parasites — Platyhelmia — Trematoda — Malacotylea — Paramphistomidæ—Fasciolidæ—Monostomidæ—Schistosomidæ—References.

SUBKINGDOM II. METAZOA.

Definition.—Metazoa are free-living or parasitic, multicellular animals, characterized by a physiological division of labour among their cells.

Tropical medicine is only concerned with parasitic Metazoa, and chiefly with those which affect man. Parasitic Metazoa may be ectoparasites—as, for example, many species of the Insecta—or endoparasites—as, for example, many worms. The ectoparasites can cause disease by introducing toxins, protozoa, or bacteria into the tissues, and in this way they are of the utmost importance as the spreaders of disease, for, as Sambon has aptly pointed out, a disease is very often limited by the special œcological conditions of the animal which spreads its germ. Many of the ectoparasites, such as mosquitoes, are temporary; or, like ticks, periodic; while others, like lice, are permanent parasites.

With regard to the endoparasites, their ill effects on the host depend upon many factors which have been recently studied by Shipley and Fearnsides in considerable detail.

The effects of metazoan parasites on their hosts depend upon the species of the parasites, their condition, the number present, their presence in certain organs, bacterial infection, their migration in the body, the loss to the host in feeding them, the damage caused by their toxins, and the condition of the host.

1. The Species of Parasite.—*Filaria* may exist in a host without apparent ill effect, but *Agchylostoma* will produce anæmia, œdema, and perhaps death.

2. The Condition of the Parasite.—The dead eggs of *Filaria* are believed to block the lymph channels, and give rise to swelling and rupture of these vessels, thus bringing about lymphangitis and elephantiasis, while the living larvæ apparently do no harm.

3. The Number of Parasites.—A few Ascarides may cause no symptoms, while a large number may lead to serious disease.

4. The Organ Affected.—Ascarides in the alimentary canal are not nearly so virulent as in the liver, while *Paragonimus westermani* in the lungs will cause a disease somewhat resembling phthisis. Ascarides may cause serious mischief in the pancreas, as observed by Chalmers, and may cause appendicitis, as noted by Blanchard, Metchnikoff, Castellani, and others.

5. Bacterial Infection caused by the Parasite.—*Trichuris trichiura* may be a harmless parasite in itself, but it is quite capable of introducing bacteria into the mucosa of the vermiform appendix and causing appendicitis, for, as is well known, it burrows in the mucosa. The fever so often found in patients suffering from agchylostomiasis is probably caused by intestinal bacteria entering the small wound produced by the agchylostome.

This method of producing ill effects upon the host appears to us to be of the greatest importance in the tropics, and is, we fear, often overlooked.

6. Migration of the Parasite in the Body.—The larvæ of *Agchylostoma* as they enter the skin cause a dermatitis known as Cooly itch, sore feet, ground itch, etc., which may be primarily due to the irritation of the worm, or secondarily to bacteria introduced into the skin by its agency. The wanderings of the larvæ of *Trichinella spiralis* through the body cause the severe symptoms of trichiniasis.

Sambon has pointed out that much that is obscure in the pathogenesis of various forms of helminthiasis might be elucidated by a better knowledge of the migrations of the entozoa in their immature stages from the time they attack the host to that of their settlement in their selective anatomical habitat. He believes that many forms do not go directly to the part in which they are usually found, but may take a very different route from that generally accepted, and may even live for a length of time in other structures before reaching such organs as the alimentary canal or nasal fossæ, which are only sought in order to enable the young to escape from the host. During these wanderings mechanical injury may be caused to the host, and pathogenic micro-organisms may be carried from one part of the body to another.

7. The Absorption of Food.—Leuckart estimates that a *Dibothriocephalus latus* gives off in a year proglottides to the weight of 140 grammes; *Tænia saginata*, 550 grammes; and *Ascaris lumbricoides*, 42 grammes of eggs in the same period.

If the number of these parasites is great, the drain on the host must be considerable, especially in children who need food for growth.

8. Toxins.—This subject has already been dealt with.

9. The Condition of the Host.—The condition of the host is also a factor in the diseases produced by these parasites, for though Ascarides may be harmless in a healthy intestine, they may perforate a typhoid or dysenteric ulcer, or a traumatic lesion of the bowel, and cause fatal peritonitis.

With regard to the question as to whether parasites ever benefit human beings, reference can be made to the belief that the development of the *Bacillus tuberculosis* Koch is delayed by the presence of entozoa in the bowels, a view which, with our Eastern experience, we are unable to support.

The old idea that worms were good for children has died out long ago, and we know of no cases of mutualism, or benefit to parasite and host, in the animal parasites of man.

Entamœba coli and *E. tropicalis* apparently do no harm to man, so that these may be taken as examples of commensalism in man, or the benefit of the messmate without injury to the host. According to some authors, with whom we do not agree, *E. coli* is not only harmless, but useful, being capable of engulfing and destroying bacteria.

True parasitism is found in those cases in which the parasite benefits and the host is injured. Chance parasites are animals which accidentally and temporarily become parasites.

The life-history of a parasite may be simple, being carried out in one host, or it may be complex, with one or more hosts for its larval stages and another for its adult condition.

Generally these hosts bear a direct relationship to one another, the intermediary host often being herbivorous, and thus becoming infected through eating fæcally contaminated food, and the definitive host being carnivorous or omnivorous, becoming infected through eating the herbivorous host of the larva.

Some parasites, particularly the Microfilariæ, show a remarkable periodicity in their habits, which appears to be associated with the means of escape from the definitive host by some intermediary host such as a mosquito or a tick, whose habits agree with the periodicity of the parasite. Such correlations are very numerous in Nature—as, for example, the opening or emitting of strong odours by certain flowers at definite times of the day or night, which accords with the habits of insects which help on their fertilization.

Tropical countries are the home *par excellence* for parasites, as the means of infection by bad sanitation, biting flies, etc., are easily available. It is therefore obvious that, as there may be many methods of infection by the mouth, the skin, and the nose, prevention is not an easy matter. It depends upon two factors—personal and public hygiene. The question of personal hygiene is the more important and more easily applied as only one person is concerned, while that of public hygiene is more expensive and not so easy to apply, as many people have to act in unison in order to produce any effect.

Personal hygiene includes such matters as personal and domestic cleanliness; protection of the skin against infection by the use of mosquito curtains and boots; avoidance of infection from domestic pets, such as dogs and cats, by not too close association with them; the protection of articles of food against flies and vermin, and the careful cooking of food and filtering of water.

With regard to public rules, the first is the proper disposal of waste, particularly of fæcal matter; careful cattle and meat inspection in well-kept slaughter-houses; and the destruction of ownerless dogs by means of a lethal chamber, in which they are killed by gas.

Classification.—The metazoan parasites of man can be arranged into phyla as follows:

Phylum I. Platyhelmia.
Phylum II. Nemathelminthes.
Phylum III. Annulata.
Phylum IV. Arthropoda.

PHYLUM I. PLATYHELMIA Lankester 1890.

Synonyms.—*Platyhelmia* Vogt 1851, *Platodes* Leuckart 1854, *Platyhelminthes* Gegenbaur 1859, *Platyhelminthes* Minot 1877.

Platyhelmia are bilaterally symmetrical Metazoa, with dorso-ventrally flattened bodies, and without a true cœlom.

The Platyhelmia are flat worms, with an oval or tape-like body, which is either covered by a ciliated epithelium, as in the free-living Turbellaria, or with a cuticle under which the surface epithelium has sunk into the parenchyma, forming the so-called subcuticular layer in the parasitic Trematoda and Cestoda. A well-developed musculo-dermal layer is present, but there is no cœlom.

The mouth is generally situated at the anterior end, when present, but it may be moved to the inferior surface, and opens, viâ a pharynx, into a forked or branched gut, which has no anal aperture. The alimentary canal may, however, be wanting (Cestoda). The excretory system begins in the so-called flame cells—*i.e.*, cells provided with a leash of cilia from which fine channels run, uniting together to form larger channels, which ultimately empty into a pair of laterally placed canals, which open to the exterior separately or together, often through an excretory vesicle.

The nervous system consists of a large, bi-lobed, cerebral ganglion, with nerves running forwards and backwards.

The Platyhelmia are mostly hermaphrodite, but may be unisexual; the ova are produced in the ovary, near which they are fertilized, and then, after receiving food-yolk from the yolk reservoir, which has received it viâ the vitelline ducts from the yolk glands, they obtain a shell from a shell gland, and then enter a uterus, in which they lie until passed to the exterior.

The male organs consist of testes, vas deferens, vesiculæ seminales, and a cirrus, with a cirrus pouch and a so-called prostate gland.

The Platyhelmia are classified into:

Class I. Turbellaria.—Free-living flat-worms.

Class II. Trematoda.—Parasitic flat-worms with an alimentary canal.

Class III. Cestoidea.—Parasitic flat-worms without an alimentary canal.

Class I. does not enter into the subject under discussion.

CLASS II. TREMATODA Rudolphi 1808.

The Trematoda are parasitic Platyhelmia, which retain the mouth and alimentary canal, but in which the epidermis not merely loses its cilia during development, but is sunk into the mesoblast after secreting the chitinous cuticle. Suckers are developed in the region of the mouth, and also on the ventral surface.

The knowledge of the Trematoda began in 1379, when Jehan de Brie discovered the liver-fluke in the sheep, which was subsequently described by Gabucinus in 1547; but it was not till the time of O. F. Müller, in 1777, that any accurate idea of their form was obtained. Zeder in 1800 made the first attempt to classify parasitic worms calling the Trematodes 'sucking-worms'; while in 1808 Rudolphi invented the name of the class, deriving it from the Greek τρηματώδης, which means 'pierced by holes.' After this date come many observers, among whom may be mentioned Laurer (whose canal still bears his name) in 1830, van Beneden in 1858, and Leuckart in 1867 (who divided them into Distomea and Polystomea), and Thomas in 1883, who worked out the development of *Fasciola hepatica*. In 1892 Monticelli revived an older classification of the group by Burmeister into three orders.

At the present time the great worker in this field of research is Looss, of the Medical School of Cairo.

Morphology.—In shape the Trematoda are generally leaf-like or tongue-shaped, and but rarely cylindrical. They are provided with a cuticle, which may have spine-like scales, and with one or two suckers, oral and ventral (often called the 'acetabulum'), which are capable of fixing the parasites by the action of their equatorial, meridional, and radial muscular fibres to the lining of the alimentary canal, or such other organ as they may inhabit.

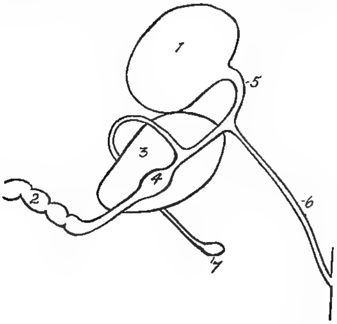

Fig. 129.—Diagram of a Type of the Female Generative Apparatus of a Trematode.

(After Stiles.)

1, Ovary; 2, uterus; 3, shell-gland; 4, oötype; 5, ovarian duct; 6, Laurer's canal; 7, Vitellarian duct.

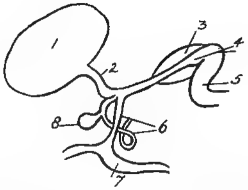

Fig. 130.—Diagram of Another Type of the Female Generative Apparatus of a Trematode.

1, Ovary; 2, ovarian duct; 3, shell-gland; 4, oötype; 5, uterus; 6, Laurer's canal; 7, Vitellarian duct; 8, receptaculum seminis.

The mouth lies in the oral sucker, and leads to a pharynx, which may may not have lateral pouches. The œsophagus may be short or long, with without a sphincter muscle, and is often provided with unicellular saliv glands. The intestinal tubules, which may be branched or simple, blindly, there being no anal aperture. The food is composed of epithe cells and blood.

The excretory system is well developed, commencing in special cells p vided with cilia (flame cells), which communicate with excretory capillar These open into canals, which anastomose freely, and then join the gather tubes, which open into an excretory vesicle. This vesicle, which may be l or short or Y-shaped, generally opens posteriorly into the foramen caud but may open dorsally in front of the acetabulum.

The sexes are but rarely separate, hermaphroditism being usual. male organs consist of testes, which may be simple or branched, and as a rule, situated posteriorly. The vas deferens leads forwards someti through a vesicula seminalis to the genital opening, below which a cir enclosed in a muscular pouch provided with glands, called the 'prosta may be found.

The female organs consist of an ovary, which may be branched and usually situated in front of the testes, and an ovarian duct, which joins w the vitellarian duct from the yolk glands, making a tube, called the 'oöty surrounded by the shell gland, in which the egg is formed (Fig. 129).

A curious little canal, Laurer's canal, joins by its inner aperture oötype near the uterine tube, while its outer aperture is found on the do surface. The homology of this little canal is not quite clear; it may b vagina. Sometimes a receptaculum seminis is present. The oötype op into the uterine tube, which is usually much coiled, and has its anter portion thickened to form the metatrema or vulva, which opens into genital orifice (Fig. 130).

The genital pore varies in position, being situated in the mid-line in fr of or behind the ventral sucker as a rule. Rarely it opens rather lateral and has a muscular depression of its own.

Life-History.—The full life-history has been worked out Thomas for *Fasciola hepatica*, under which heading details will given, and by Looss for *Paramphistomum cervi*. Some other li histories are also known, but do not concern us.

Typically there is an alternation of generations where one sexu generation is followed by two asexual generations. Usually t hosts are required, but perhaps one may be sufficient in certa circumstances, for the whole life cycle.

Habitat.—These parasites are found in all classes of the ver brates, and may occur in any of the organs, but the most comm in man are in the urinary bladder, the intestinal tract, the lun and the liver. It is important to remember that the adu parasites may live in domestic animals, especially in cats, a that they may affect horses and cattle. Further, the encystme on grass, water-weeds, etc., must be borne in mind, and the fa that the miracidium swims about in water, and may perhaps pier the skin of a human being bathing therein, though this last meth has never, so far, been definitely proved.

Pathogenesis.—Apparently the smaller forms can live in hum beings without being suspected, but irritation of the bladder, liv intestine, and lungs may result either as the effect of the eggs or the parasite. Then, again, they may pass into the blood-stream a infect the whole body.

Diagnosis.—The systematic examination of the fæces by the microscope, especially in cases of diarrhœa, is the only certain method of diagnosis.

Treatment.—The treatment of infections by these animals may be said to be useless. The intestinal ones might be tried to be killed or expelled by chloroform mixed with eucalyptol, as described in the chapter on Agchylostomiasis, or by extract of male fern.

Prophylaxis.—We do not know enough about the life-cycle to lay down general rules about prophylaxis, but it will be obvious that the cat, the dog, the horse, and cattle, are indirect sources of infection, while green vegetables, particularly those not cooked, must be regarded with suspicion, and so must that delicacy, the edible snail, which may not be properly cooked.

The classification of the Trematoda is as follows :

ORDER I. HETEROCOTYLEA Monticelli.

Synonyms.—*Polystomea* Leuckart, *Pectobothrii* Burmeister, and *Monogenea* van Beneden.

Trematodes, generally ectoparasitic, but may be endoparasitic in amphibia and tortoises.

ORDER II. ASPIDOCOTYLEA Monticelli.

Synonym.—*Aspidobothrii* Burmeister.

Lowly organized endoparasitic trematodes, with one large sucker occupying the whole ventral surface, found in tortoises, marine fish, and shellfish.

ORDER III. MALACOCOTYLEA Monticelli.

Synonyms.—*Distomea* Leuckart, *Malacobothrii* Burmeister, and *Digenea* van Beneden.

Typical endoparasitic trematodes, with never more than two sucking discs, oral and ventral, and a Laurer's canal.

The Malacocotylea include all the human trematode parasites, and are subdivided into groups :

DIVISION A. METASTATICA Leuckart.—Development without alternation of generations.

DIVISION B. DIGENEA Leuckart.—Development with alternation of generations. The Digenea contain the human parasites.

Family 1. *Paramphistomidæ.*—Digenea with ventral sucker at the posterior end, opening of the excretory apparatus on the dorsal surface. Hermaphrodites.

Family 2. *Fasciolidæ.*—Digenea with oral and ventral suckers ; excretory pore at the posterior border. Hermaphrodites.

Family 3. *Monostomidæ.*—Digenea with only an oral sucker. Ventral sucker absent.

Family 4. *Schistosomidæ.*—Digenea resembling the Fasciolidæ, but with separate sexes.

The parasites known in man may be summarized as follows :

Order : Malacocotylea.
Suborder : Digenea.

Family.	Genus.	Species.
Paramphistomidæ	Gastrodiscus ..	1. G. hominis L. and Mc
	Cladorchis ..	2. C. watsoni Conynghar
Fasciolidæ ..	Fasciola	3. F. hepatica L.
		4. F. gigantica Cobbold.
	Fascioletta ..	5. F. ilocana Garrison.
	Agamodistomum	6. A. ophthalmobium Di
	Fasciolopsis ..	7. F. buski Lankester.
		8. F. fülleborni Rodenwa
		9. F. (?) Heanley.
	Opisthorchis ..	10. O. felineus Rivolta.
		11. O. noverca Braun.
	Clonorchis ..	12. C. sinensis Cobb.
		13. C. endemicus Baelz.
		14. C. (?) Looss.
	Metorchis ..	15. M. truncatus Rudolph
	Paragonimus ..	16. P. westermani Kerber
	Heterophyes ..	17. H. heterophyes Von S
	Dicrocœlium ..	18. D. lanceatum Stil Hass.
Monostomidæ ..	Monostomulum ..	19. M. lentis Gesch.
Schistosomidæ ..	Schistosoma ..	20. S. hæmatobium Bilh.
		21. S. mansoni Sambon.
		22. S. japonicum Kats.

FAMILY I. PARAMPHISTOMIDÆ Fischoeder 1903.

Digenea with ventral sucker at the posterior end of the body, a with the excretory pore on the dorsal surface. Hermaphrodites

This family, which used to be called the Amphistomidæ, und went a thorough revision in 1903 at the hands of Fischoeder, wh article should be consulted if detailed information is desired.

He classifies the family as follows :

SUBFAMILY I. PARAMPHISTOMINÆ.

Genera.—(1) *Paramphistomum* ; (2) *Stephanopharynx* ; (3) *Gas thylax.*

SUBFAMILY II. CLADORCHINÆ.

Genera.—(4) *Cladorchis* ; (5) *Chiorchis* ; (6) *Gastrodiscus* ; *Homologaster* ; (8) *Balanorchis.*

The only known human parasites come under the genera *Clad chis* and *Gastrodiscus.*

SUBFAMILY II. CLADORCHINÆ Fischoeder 1903.

Paramphistomidæ, with a pharyngeal sac, ramified testes a cirrus sac. Body dorso-ventrally flattened, with the acetabul usually situated ventrally, rarely posteriorly.

Habitat.—Alimentary canal of mammals.

Genus.—*Cladorchis.*

Cladorchis Fischoeder 1901.

Cladorchinæ with body not divided into anterior and posterior portions, and having the lateral edges round and the ventral surface slightly hollowed. Pharynx spherical with lateral diverticula, œsophagus with a circular sphincter muscle. Oral sucker not well marked. Ventral sucker large with small opening. Ventral surface wrinkled.

Cladorchis watsoni Conyngham 1904.

Synonyms.—*Amphistomum watsoni* Conyngham 1904, *Paramphistomum watsoni* Conyngham 1904.

History.—*Cladorchis watsoni* was first discovered in the duodenum and upper part of the jejunum of a negro who had come from Adamawa, in German West Africa, to Northern Nigeria. Since its discovery it has been reported as common near Lake Chad. It was first described by Conyngham, and later in detail by Shipley.

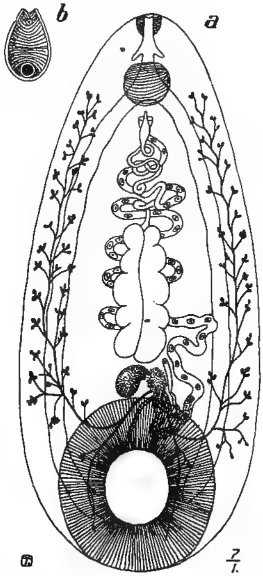

Fig. 131.—Cladorchis watsoni.
(After Shipley.)
a, Schematic ; *b*,. natural size.

Morphology.—The parasite is reddish-yellow when fresh, 8 to 10 millimetres in length by 4 to 5 millimetres in breadth. In shape it is oval. The ventral sucker is large and situated posteriorly, while the oral sucker is so small as to be hardly worthy of being considered a true sucker. The pharynx is spherical, with two lateral diverticula, called the 'pharyngeal pouches.' The œsophagus divides into two intestinal cæca about the level of the junction of the anterior third with the posterior two-thirds of the body, and is here surrounded by a sphincter muscle. The excretory pore opens in the middle line dorsal to the posterior sucker. The excretory vesicle is capacious, and lies over that sucker. The genital papilla is situated in the mid-ventral line, about the junction of the anterior quarter with the posterior three-quarters of the body, and on it open the canal of the cirrus and the metatrema. The testes are deeply lobulated. The vas deferens runs into a vesicula seminalis, which opens into the cirrus canal.

The ovary lies close behind the testes, and rather to the right of the body. The ovarian duct curves backwards, and is almost at once surrounded by the shell gland, when it may be called the 'oötype,' which just behind the shell gland receives the vitellarian duct and the inner end of Laurer's canal.

The uterus, full of eggs, coils over the testes and runs as far forwards as their anterior border, where it becomes thick and muscular, and is called the 'metatrema.' The eggs are large (122 μ in length by 80 μ in breadth).

Life-History.—The life cycle is not known, but it is believed t the usual host is a herbivorous animal. It is said to be especia common in children.

Pathogenesis.—It may perhaps cause diarrhœa and anæmia. post-mortem showed the mucosa slightly congested.

Diagnosis.—By recognition of the trematodes in the fæces.

Treatment.—The eucalyptus and chloroform mixture advised agchylostomiasis.

Gastrodiscus Leuckart 1877.

Clonorchinæ with bodies slender anteriorly and broadened p teriorly into a large concave disc, at whose posterior border the sm ventral sucker lies. The pharynx has two pouches, like diverticu Common in the Equidæ in Egypt and India. The horse species known in Senegal and Guadeloupe. The parasites so commo met with in *Bos indicus* in Ceylon are Paramphistomidæ, and that *Bos bubalus* is *Gastrothylax cruminifer* Crepl.

Gastrodiscus hominis Lewis and McConnell 1876.

Synonym.—*Amphistomum hominis* Lewis and McConnell.

History.—It was first described in 1876 by Lewis and McConn who found it in hundreds attached by its posterior sucker to t mucosa of the cæcum, vermiform appendix, and ascending colon an Assamese. Since then it has been twice reported in natives India, and perhaps it may be common. We have not met with in Ceylon, though there was a small jar in the Medical Coll Museum labelled *Amphistomum hominis*, but without a histo The common belief is that it exists in the horse, and finds its w into man from this animal.

Morphology.—The parasite is reddish-coloured, 8 to 10 millimetres in len and 4 to 5 millimetres in greatest breadth, tapering to 2·5 millimetres in fro The thickness is about 4 millimetres. The posterior end of the body prese a large disc, on the hinder border of which lies the acetabulum. The res the body is thin, tapering to the mouth. The genital pore is at a level w the bifurcation of the intestine. The testes are double, with a sinuous deferens. The uterus and the yolk glands are situated laterally. The e are oval, 0·15 millimetre in length and 0·072 millimetre in breadth.

Pathogenesis.—It is not known whether these parasites cau any disease.

FAMILY II. FASCIOLIDÆ Railliet.

Hermaphrodite Digenea with oral and ventral (acetabulu suckers. The excretory pore is on the posterior border (foram caudale).

The Fasciolidæ contain a number of genera, of which species ha been found in man: (1) *Fasciola* Linnæus 1758; (2) *Fasciole* Garrison 1908; (3) *Agamodistomum* Stiles; (4) *Fasciolopsis* Lo 1898; (5) *Opisthorchis* R. Blanchard 1845; (6) *Clonorchis* Lo 1907; (7) *Metorchis;* (8) *Paragonimus* Braun 1899; (9) *Heteroph* Cobbold 1866; (10) *Dicrocœlium* Dujardin 1845.

The table on pp. 356, 357 gives some of the characters by whi they can be recognized :

Fasciola Linnæus 1758.

Large Fasciolidæ with leaf-like bodies, with the anterior end shaped into a conical head and with the ventral sucker situated near the mouth. Cuticle covered with spines.

Fasciola hepatica Linnæus 1758.

Synonyms.—*Distomum hepaticum* Retz 1786, *Fasciola humana* Gmel 1789, *D. caviæ* Sons 1890, *Cladocœlium hepaticum* Stoss 1892.

History.—*Fasciola hepatica*, the liver-fluke, is a parasite of sheep, oxen, goats, horses, and many other herbivorous animals in Europe, North Africa, North and South America, Australia, Tasmania, Japan, China, Burmah, and India. It is said to be extremely common in Burmah and Egypt.

It has been found in man several times, and apparently usually in the liver, but it has been recorded in the bloodvessels, in a swelling on the sole of the foot, in abscesses about the head, and in a swelling in the right hypochondriac region. It is probable that *Distomum oculi humani* Ammon 1833 and *Monostomum lentis* Von Nordmann 1832 may have been young liver-flukes.

Morphology.—*Fasciola hepatica* is a flat, oval animal, with an anterior triangular projection. Length, 20 to 30 millimetres; breadth, 8 to 13 millimetres. The cuticle is covered with minute pointed scales directed backwards. There are two suckers—an oral, which is situated at the anterior end of the animal, and surrounds the mouth opening, and a ventral, the acetabulum, which is a muscular cup, situated in the median line near the junction of the anterior projection with the rest of the body. The mouth leads into a muscular pharynx, which passes via a short œsophagus into the intestine, which divides just in front of the genital aperture into two tubes running to the posterior end of the body, giving off numerous branched cæca.

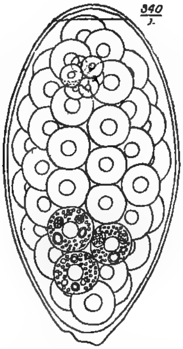

FIG. 132.—EGG OF FASCIOLA HEPATICA.

(After Thomas, from the *Quarterly Journal of Microscopical Science.*)

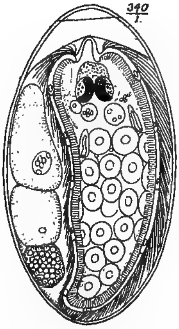

FIG. 133.—THE MIRACIDIUM OF FASCIOLA HEPATICA.

(After Thomas, from the *Quarterly Journal of Microscopical Science.*)

The excretory system starts with dilated tubules, into which project the cilia of the so-called flame cells. The ducts, which freely anastomose, open into a main duct, which runs directly backwards to open at a median pore at the posterior end of the body.

DIAGNOSTIC TABLE OF THE GENER

Genera.	Size and Shape.	Anterior End.	Cuticular Spines.	Acetabulum.	Intestinal Cæca.	Ge
Fasciola ..	Large and leaf-like	Head cone	Present	Well developed near oral sucker	Branched	M ar ac
Fascioletta ..	Very small and narrow	No head cone	Absent	Large and prominent	Not branched	Le lin to a
Fasciolopsis ..	Large	No head cone	Absent	Large, elongated posteriorly	Not branched	A b
Opisthorchis ..	Long and flat	No head cone	Absent	Small and close to oral sucker	Not branched	M ar ac
Clonorchis ..	Body pigmented, long and narrow	No head cone	Absent	Small	Not branched	M an ace
Metorchis ..	Slender	Pointed	Present	About middle of body	Not branched	M an ace
Paragonimus ..	Broad and thick	Rounded	Present	About middle of body	Not branched	Nea m ace littl
Heterophyes ..	Small	Narrow and movable	Present	About middle of body	Not branched	L behi bul chiti
Dicrocœlium ..	Medium-sized	Pointed	Absent	Near oral sucker	Not branched	Clo p

In addition to the above, immatur

IOLIDÆ CONTAINING HUMAN PARASITES.

ion of tes.	Situation of Uterus.	Receptaculum Seminis.	Vesicula Seminalis.	Yolk Glands.	Cirrus Pouch.	Excretory Vesicle.	Œsophagus.	Hal
ched, ated riorly	In front of sexual glands	Nil	Present	Spread all along sides	Present	Well developed	Short	Li
bate, ated riorly	Between acetabulum and anterior testes	Nil	Present	Posterior half of body	Well developed	Tubular	Short	In ti
nched, iated eriorly	In front of sexual glands	Nil	Tubular	Spread all along sides	Long and cylindrical	Tubular	Short or absent	In t
ulated, uated teriorly	In front of sexual glands	Present	—	Middle one-third	Nil	Y-shaped	Short	L an te
uated oster- y, and nched	In front of sexual glands	Present	Present	Middle two-thirds at the sides	Nil	Not Y-shaped; tubular	Short	L
iptical, uated teriorly	In front of sexual glands	Present	Nil (?)	Middle one-third	Nil	—	Short	I
ound rami- d pos- riorly	Behind acetabulum	Nil	Nil (?)	Spread all along the sides	Nil	Very large, extending forwards to pharynx	Short	L c o
mooth oster- riorly	In front of testes	Present	Present	At the sides posteriorly	Nil	Tubular	Long	I
mooth just ehind tabulum	Posteriorly	Present	—	Middle one-fifth	Present	Tubular	Short	]

ssified under the term 'Agamodistomum.'

The two testes are much-branched tubes, lying in the middle of the bo of equal size, one lying in front of the other ; from each a vas deferens r as far as the ventral sucker, where it opens into an elongated sac, the vesic seminalis, from which the ductus ejaculatorius runs to the end of a la muscular organ, called the cirrus, which lies in a sac situate just in fron the ventral sucker. The genital opening through which the cirrus can protruded is situated between the two suckers on the ventral surface.

The branched and tubular ovary lies on the right, in front of the ante testes. The ovarian duct runs backwards to join the middle line with median vitellarian duct from the yolk reservoir, into which open the vi larian ducts from the large branched yolk glands lying on either side of body, from the level of the ventral sucker to the posterior extremity.

The junction of these two ducts is surrounded by the shell gland, and for a much-convoluted tube, the uterus, which is joined close to its commen ment by a little tube, Laurer's canal, opening on to the dorsal surface.

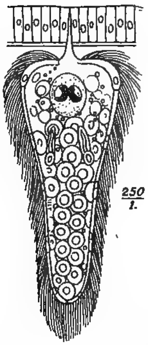

FIG. 134.—THE LARVA OF FASCIOLA HEPATICA.

(After Thomas, from the *Quarterly Journal of Microscopical Science.*)

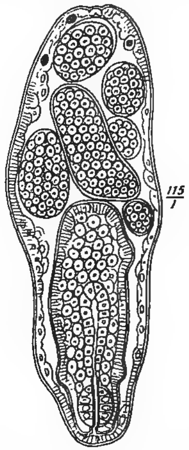

FIG. 135.—THE SPOROCYST O FASCIOLA HEPATICA.

(After Thomas, from the *Quart Journal of Microscopical Scien*

uterus, which is generally full of eggs, opens on the left side of the base the cirrus.

The nervous system consists of a nerve collar around the pharynx, fr which two nerve cords run backwards along the sides of the body.

Life-History.—The ovum starts from the ovary and travels along ovarian duct, where it is fertilized, after which it is surrounded by a la number of yolk cells, and then by a shell formed from the secretion of shell gland. The egg now passes forwards into the uterus, and is eviden deposited in the bile-passages and escapes in the fæces. It is oval, yellowi brown, with a cap-like lid 0·13 to 0·145 millimetre in length by 0·07 to c millimetre in breadth, and is seen to enclose a mass of yolk cells with ovum, which now segments and grows, using up the yolk cells, formin young form, called a 'miracidium,' 0·13 by 0·027 millimetre, which a few weeks escapes by the opercular opening if the egg is in water, a being ciliated, swims about as a conical larva, with a little anterior pap and two eye-spots. It has a cuticular epithelium, under which are musc layers, and contains a simple sac, like an alimentary canal, a cerebral g glion, and an excretory system. There is a segmentation cavity (forming body cavity) between the alimentary canal and the body-wall.

It now bores its way into the pulmonary cavity of some snail by mea of its anterior papilla; otherwise it dies in about eight hours. T varieties of snail hosts are: *Linnæus truncatulus* Müll, in Europe, Asi Africa; *L. oahuensis* in the Sandwich Islands; *L. viator* Orb in Sout America; *L. humilis* Say in North America, in which it loses all i organs, and increases in size rapidly, while cells grow from the wall into t primary body cavity, so that a cyst is formed, called the 'sporocyst.' Th has an external cuticle, a thin muscular layer, and an epithelial lined cavit containing collections of cells, which develop into cylindrical forms, possessing a simple, short, tube-like alimentary canal, with a pharynx, glands, an intestine, and a genital pore near the anterior end. These forms, which a called *Rediæ*, after the celebrated biologist Redi, force their way out of t

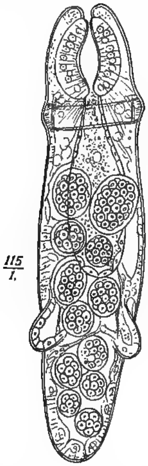

FIG. 136.—THE REDIA OF FASCIOLA HEPATICA.

(After Thomas, from the *Quarterly Journal of Microscopical Science.*)

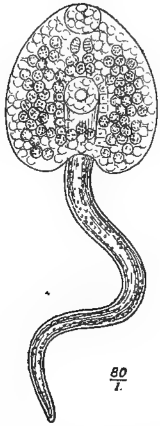

FIG. 137.—THE CERCARIA OF FASCIOLA HEPATICA.

(After Thomas, from the *Quarterly Journal of Microscopical Science.*)

sporocyst by making a wound, which heals readily, and then wander abo the snail, being especially abundant in the liver. When fully formed the have a ridge running round the anterior end, and a pair of blunt process for locomotion posteriorly.

Inside the *Rediæ* cells bud off from the body-wall and form the *Cercari* which are not unlike a young *Fasciola* with a tail.

The *Cercariæ* possess cutaneous glands for the purpose of secreting t cyst-wall of the next stage. They escape from the *Rediæ* by means of t genital pore, and, leaving the snail, swim about in the water for some tim finally becoming encysted on grass or water-weeds, and are then eaten b sheep, inside which they escape from the cyst, and, working their way alon the bile-ducts, develop in six weeks into sexually mature flukes.

Habitat.—The liver-fluke usually lives in the sheep, in which it causes t disease called '**sheep-rot**'; but infection can spread to man and cause diseas as will be described later.

Fasciola gigantica Cobbold 1856.

Synonym.—*Fasciola angusta* Railliet 1895, *F. gigantea* Cobb 1858.

F. gigantica, which is nearly allied to *F. hepatica*, is fou in oxen in Senegambia, and is believed to have occurred in man, for a parasite somewhat resembling it was expelled from lung during a fit of coughing associated with hæmoptysis, but th is some doubt as to whether it was not different from Cobbol species.

Its length was 26 to 28 millimetres and its breadth 6 to 8 mi metres, but it was contracted. It caused fever, cough, and slig hæmoptysis.

Fascioletta Garrison 1908.

Fasciolidæ, with small elongated bodies, broader anteriorly th posteriorly, without cuticular spines, and with large promine acetabulum. Œsophagus short, intestinal cæca unbranched. E cretory vesicle tubular. Genital pores anterior to the acetabulu Testes compact, situate in the median line one behind the oth Cirrus and pouch well developed. Ovary compact; no recep culum seminis; Laurer's canal present. Yolk glands well develop in the posterior fifth of the body; well-developed shell gland a uterus, which lies between the ovary behind and the acetabulum front. Ova large and operculated.

Fascioletta ilocana Garrison 1908.

History.—*Fascioletta ilocana* was discovered and described Garrison, who in 1907 noticed peculiar eggs in the fæces of Philippi prisoners in Bilibid Prison in Manila, and subsequently, after tre ment with male-fern, obtained a number of small trematodes.

Morphology.—*Fascioletta ilocana* is a very small trematode, measuring 6 millimetres in length by 0·75 to 1·35 millimetres in breadth, and 0·5 t millimetre in thickness. Posteriorly it is attenuated. The acetabulun about three times the size of the oral sucker, which is either terminal or sligh ventro-subterminal. The prepharynx is long, the pharynx globular; œsophagus short, bifurcating just anterior to the genital pore into the intesti cæca. The genital pores open separately a little behind the halfway po between the pharynx and the acetabulum.

The cirrus pouch is well developed, and contains posteriorly the vesic seminalis, into which open the vasa deferentia, and which gives rise to long coiled cirrus. Each testis shows an anterior and a posterior lo The ovary is globular, the yolk glands well developed, and the uterus fa developed. Ova 88·8 to 114·7 μ long by 53·5 to 81·9 μ broad.

Life-History.—Nothing is known of the life-history beyond fact that a miracidium hatches in about ten days after the eggs ha left the host.

Habitat.—The intestine of man in Luzon, in the Philipp Islands.

Pathogenesis.—It is probable that the worm is non-pathogenic

Agamodistomum Stiles.

Agamodistomum is an artificial collective group, designed to contai larval stages of Fasciolidæ which have not developed far enough to allow o their being determined generically.

There is no type species.

Agamodistomum ophthalmobium Diesing 1850.

Synonym.—*Distomum oculi humani* Ammon 1832.

Ammon found four specimens of a parasite, 0·5 to 1·0 millimetre in length between the capsule and the opaque lens of a child, aged five months, i Dresden. There were no lateral branches to the intestinal cæca. It i possible that this was really a young *F. hepatica.*

Fasciolopsis Looss 1898.

Fasciolidæ without a head cone and without cuticular scale Acetabulum prolonged posteriorly into a pouch ; cirrus pouch ver long and cylindrical ; intestinal cæca without branches.

Species.—*Fasciolopsis buski ; F. fülleborni and Kwan's fluke.*

Fasciolopsis buski Lankester 1857.

Synonyms.—*Distomum buski* Lankester 1857, *D. crassum* Busk 1859, *nec* v. Siebold 1836 ; *Distomum rathouisi* Poirier 1887.

History. — *Fasciolopsis buski* is a very large trematode, which was first discovered by Busk in the duodenum of a Lascar who died in the Seamen's Hospital in 1843. In 1857 it was named by Lankester, and in 1859 described by Cobbold.

It appears to be by no means uncommon in man and pigs in South China, and is known in Borneo, the Straits Settlements, Assam and India. It is the same as *F. rathouisi.*

Morphology.—It is a large, thick, brown, smooth trematode, 24 to 70 millimetres in length and 5·5 to 14 millimetres in breadth. The oral sucker, and acetabulum are in the proportion of 0·5 2·0. The pharynx is globular and there is a prepharynx, with a sphincter. The œsophagus is short, and the intestinal cæca are not branched, and extend to the posterior border. The genital pore is situated anteriorly to the acetabulum, but the most remarkable feature is the very long cirrus, about one-fourth the length of body. The testes lie posteriorly, with the ovary and the uterus in fro The yolk glands are extensive, like in *F. hepatica.*

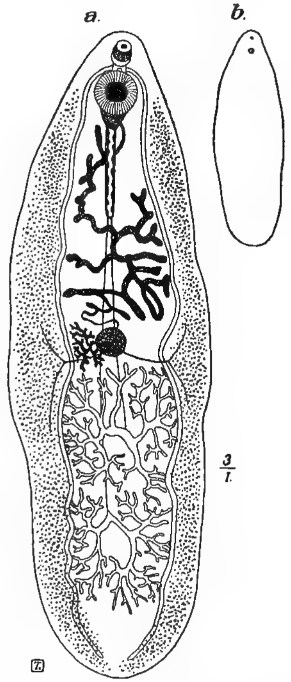

Fig. 138.—Fasciolopsis busi (After Odhner, from the *Centr blatt für Bakteriologie.*)

a, Schematic ; *b*, natural siz

The eggs are 0·12 to 0·13 millimetre in length and 0·077 to 0·08 breadth.

Habitat.—The intestine of the pig and man.

Pathogenesis.—It is believed to cause dysenteric diarrhœa.

Fasciolopsis fülleborni Rodenwalt 1909.

This worm was discovered and described by Rodenwalt in 19 being found in the motions of an Indian in Hamburg.

Morphology.—The parasite is very large, measuring from 30 to 50 mi metres in length, and from 14 to 16 millimetres in breadth. The oral suc and acetabulum are in the proportions of 0·75 to 2·6. There is a prephary and pharynx, but no œsophagus.

The intestinal cæca are long and wavy, and extend to the posterior e The genital apertures lie in front of the acetabulum.

The cirrus sac is very long and well developed, and the testes lie behind t ovary and the oötype. The latter is much larger than in *F. buski*, and is o instead of being round. The yolk glands extend from the acetabulum to t posterior end of the body, being situated laterally. The excretory vesi is well developed.

The eggs measure 0·1 millimetre in length by 0·073 millimetre in breadt

Habitat.—Intestine of man.

Pathogenesis.—The patient harbouring it was suffering fr fever, which had been diagnosed as typhoid.

Kwan's Fluke.

Under this term Heanley has described a trematode found Dr. Kwan King Hung in a child in the island of Hong Kong. length it is 2 inches, in breadth $\frac{1}{2}$ inch, and is subdivisible in a small, narrow, anterior portion and a large, broader, posteri portion. The anterior portion is $\frac{1}{8}$ inch long and $\frac{1}{16}$ inch broa oval in shape, with a depression on one surface, bounded by a l which projects backwards. The cuticle possessed spines.

The intestine was not clearly seen, but the cæca were unbranche The testes were large and placed one behind the other. The ova was branched, and it—the shell gland and the yolk glands (whi met each other posteriorly)—resembled those of *F. buski*.

Pathogenesis.—The patient suffered from vomiting, which result in the expulsion of the flat-worms.

Opisthorchis R. Blanchard 1845.

Fasciolidæ with long flattened body and somewhat point anterior extremity, with a cuticle usually without spines, sucke small, intestinal cæca unbranched, yolk glands situate lateral and not extending beyond the ventral sucker in front, testes in t posterior part of the body, one behind the other.

Habitat.—The bile-ducts.

The species of this genus are separated from one another with gre difficulty.

The following are found in man: *Opisthorchis felineus* Rivol 1885, *Opisthorchis noverca* Braun 1903.

Opisthorchis felineus Rivolta 1885.

Synonyms.—*Distoma conus* Gurlt 1831, *nec* Creplin 1825; *D lanceolatum* v. Siebold 1836, *nec* Mehlis 1825; *D. sibiricun* Winogr 1892; *D. tenuicolle* Mühl 1896, p.p.

Opisthorchis felineus lives in the gall-bladder and bile-ducts o the domestic cat, and is also found in dogs in Europe. The Nortl American species is different (*O. pseudo-felineus*).

In human beings it is apparently a common parasite in Siberia where it was first found by Winogradoff in Tomsk.

Morphology.—It is reddish-yellow in colour, with a conical neck at th level of the ventral sucker, marked by a shallow constriction.

The length is from 8 to 11 millimetres and the breadth 1·5 to 2 millimetres The testes lie in the posterior part of the body, one behind the other. The yol glands are situate on either side of the middle third of the body, beginnin behind the ventral sucker and terminating about the level of the ovary.

The genital pore is close in front of the ventral sucker.

The eggs are oval, with a well-defined operculum (30 μ by 11 μ).

Life-History.—The parasites live in the bile-duct, and the eggs containing a ciliated miracidium, escape in the fæces. Furthe development is not known; perhaps it takes place in a fish whic infects men and cats.

Pathogenesis.—It causes inflammation, dilatation of the bile ducts in man, with atrophy of the liver substance, ascites, an icterus.

Opisthorchis noverca Braun 1903.

Synonym.—*Distoma conjunctum* Lewis and Cunningham 1872 *nec* Cobbold 1859.

Cobbold in 1858 found a little fluke (*D. conjunctum*) in the bile ducts of *Canis fulvus* Lewis, the American fox. Fourteen year later Lewis and Cunningham found what was considered to be th same fluke in Indian pariah dogs, and in 1874 McConnell reporte the presence of the same fluke in human beings in Calcutta.

Braun in 1903 pointed out that the two parasites are quite different, and gave the name of *Opisthorchis noverca* to the Indian species it being smaller and having slightly different arrangements in it yolk glands and suckers.

Morphology.—It is lancet-shaped, with anterior and posterior extremitie pointed body, covered with spines; 9·5 to 12·7 millimetres in length, an 2·5 millimetres in breadth, with two suckers very close together, the anterio being larger than the posterior. The genital pore opens just in front of th ventral sucker. The pharynx is spheroidal, and the intestinal cæca exten far back. The two testes are very distinct, the anterior rounded and th posterior lobate. The ovary is slightly lobate, and it and the uterus ar situated medianly. The yolk glands lie laterally in the middle third, extending from behind the ventral sucker to the back of the testes. There is n cirrus pouch. The eggs are oval (0·034 by 0·021 millimetre).

Habitat.—The dog and man.

Pathogenesis.—Not known.

Clonorchis Looss 1907.

Fasciolidæ, characterized by the fact that the testes are n notched or lobate, but distinctly ramified, the branches crossi the intestinal cæca on their ventı side, and extending very near t body margin. The excretory vesi is simply an unpaired tube, whi becomes somewhat widened at ı anterior end, assuming sometimes t shape of an irregular triangle.

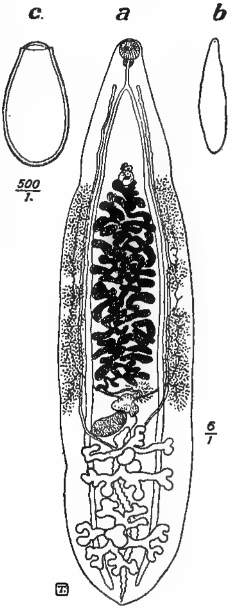

Fig. 139.—Clonorchis sinensis. (After Looss, from the *Annals of Tropical Medicine and Parasitology*.)

a, Schematic; *b*, natural size; *c*, egg × 500.

Species.—*Clonorchis sinensis* Co bold 1875, *Clonorchis endemicus* Ba 1883.

Clonorchis sinensis Cobbold 187

Synonyms.—*Distoma sinense* Co bold 1875, *D. spathulatum* Leucka 1876, *Distomum hepatis innocu* Baelz 1883.

Clonorchis sinensis was first d covered by McConnell in 1874 in t liver of a Chinaman. Until recent it was believed to be an *Opisthorch* but in 1907 Looss gave reasons w it should be placed in the new gen *Clonorchis*. As far as is known occurs principally in China a Japan, and has not yet been fou in animals.

Morphology.—*Clonorchis sinensis* is white, or yellowish-red, or browni narrow trematode, 13 to 19 millimet in length, and 3 to 4 millimetres breadth. The pigmentation is due the deposit of fine yellowish or bro granules in the body parenchyma. The ramifications of the testes are long, anterior arising from four and the posterior from five main stems, with so times ventral bulgings. The ovary is trilobate, but may show three six smaller lobules. The yolk glands reach from the ventral sucker to level of the ovary, and are peculiar in that certain groups of follicles rem undeveloped. In perfectly mature specimens the seminal vesicle exte back as far as the middle of the uterus. The eggs are generally narro towards the anterior end, and have a rather high lid, with a sharply proj ing brim (these peculiarities may be absent). The egg is 29 μ in length 16 μ in breadth.

Habitat.—Only known in man.

Clonorchis endemicus Baelz 1883.

Synonym.—*Distoma hepatis endemicum sive perniciosum* Ba 1883, *Distoma japonicum* R. Blanchard 1886.

History.—In 1883 flukes were first described in the liver of hun beings in Japan by Kiyono, Nakahama, Suga, and Yamagata, an a little later in the same year Baelz reported the occurrence of tw hepatic distoma in Japan.

1. *Distoma hepatis innocuum*, up to 20 millimetres in length, wit a lighter-coloured uterus of larger volume, with slightly larger ova, 21 to 36 μ in length by 18 to 20 μ in breadth, and with a black granular pigment in its excretory apparatus and body parenchyma. It caused little or no symptoms in human beings, and was found accidentally in post-mortems.

2. *Distoma hepatis endemicum sive perniciosum*, which was smaller, 8 to 11 millimetres in length, and did not possess the above characters, while its eggs were only 20 to 30 μ in length by 15 to 17 μ in breadth.

These were confused with McConnell's parasite, which is now called *Clonorchis sinensis*, and of which *Distoma hepatis innocuum* is merely a synonym. Looss points out that the description given since 1883 of *Opisthorchis sinensis* is that of *D. hepatis endemicum*, which he now separates distinctly as *Clonorchis endemicus* Baelz 1883.

It is found in Japan, where it is common, and in Annam and Tonkin, in man, cats, dogs, and pigs

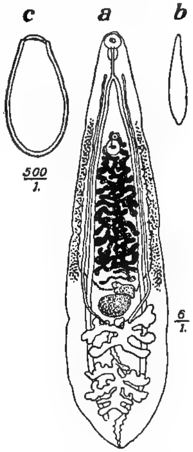

FIG. 140.—CLONORCHI ENDEMICUS.

(After Looss, from th *Annals of Tropic Medicine and Para sitology.*)

a, Schematic; *b*, Natur size; *c*, egg × 500.

Morphology.—From 6 to 13 millimetres in length by 1·8 to 2·6 millimetres in breadth. Oral sucker, 0·43 to 0·45 millimetre in diameter; ventral sucker, 0·37 to 0·40 millimetre in diameter. Ratio of the two sucker 13 : 12 and 15 : 12. No pigment granules in the parenchyma. The yol glands are like *C. sinensis* but there are fewer undeveloped groups of follicle The eggs are 26 μ long and 15 μ broad, on an average, with a rather flat lid.

Habitat.—It is found in cats, dogs, hogs, and men.

Pathogenesis.—Enlargement of the liver, and diarrhœa.

A Possible Feline Clonorchis (or Opisthorchis).

Looss draws attention to the fact that Ijima, in 1886, describes a *Distomu* from the liver of a cat in Japan, with fine spines, and smaller than *C. endemicu* which is to be looked upon as a normal parasite of the cat. It is only 4·5 milli metres in length by 0·9 millimetre in breadth. It may be a *Clonorchis* or a *Opisthorchis*.

Katsurada, in 1900, published a paper based upon seventy-six post-mortem with an enormous number of parasites, among which he mentioned thre found in a man from the province of Saga, with an average length of 5·16 milli metres and breadth of 0·96 millimetre, which Looss considers can only b explained as an infection with a feline species.

Habitat.—Cats and man (?).

Metorchis.

Fasciolidæ, somewhat slender in shape, with the anterior end pointed the posterior truncated, with cuticular spines, and suckers nearly equa size. Œsophagus very small, with long unbranched intestinal cæca. Gen pore opens in the mid-line anterior to the acetabulum.

The ellipsoidal testes are situate posteriorly; yolk glands only in lateral portion of the middle one-third of the body.

Metorchis truncatus Rudolphi 1819.

Braun believes that one of Winogradoff's Siberian parasites was *Opisthorchis felineus*, because it had cuticular spines, but *Metorchis trunca* which is found in the liver of cats, and is mainly characterized by its poste extremity being truncated and provided with a tuberosity like a suc This, however, is entirely a matter of conjecture.

Paragonimus Braun 1899.

Fasciolidæ with thick, oval, or broad, fusiform bodies, alm circular on transverse section. Cuticle, with scale-like spin Suckers separated by half the length of the body. The intesti cæca are wavy, and run to the posterior end of the body, but unbranched. The excretory vesicle runs from the pharynx ba wards to its aperture on the posterior margin of the body. T genital pore is just behind the ventral sucker. There is no cir pouch, and no receptaculum seminis.

Habitat.—In the lungs and other organs of mammals.

Paragonimus westermani Kerbert 1878.

Synonyms.—*Distoma westermani* Kerbert 1878, *D. ring* Cobbold 1880, *D. hepaticum* Miura 1889, *D. pulmonale* Baelz 18 *D. pulmonis* Suga 1883, *D. cerebrale* Yamagiwa 1890, *Mesogonim westermani* Raillet 1890, *M. pulmonale* Stossich 1892.

History.—*Paragonimus westermani* was discovered by Kerb in 1878 in the lungs of two Bengal tigers, who died respectively the Zoological Gardens of Amsterdam and Hamburg.

In 1880 Baelz found in the sputum of cases of hæmoptysis bodi which he took to be psorosperms, and therefore called the disea gregarinosis pulmonum, but when these were referred to Leucka he said that they were eggs of a *Distomum*. In the same ye Manson found what he took to be eggs of some parasite in a case hæmoptysis, in a Chinaman from Northern Formosa, and later saw a Portuguese with hæmoptysis and obscure thoracic sympto who lived in Tamsui in North Formosa.

This man died in Formosa, and Dr. Ringer, who performed post-mortem, discovered in the lungs a minute, fleshy, slight flattened, oval body, grey in colour, and about a quarter of an in in length, which expelled some brownish material from a minu orifice near one end.

This specimen was sent to Manson, who noted the same eggs as had found in the Chinaman already mentioned, and then forward the parasite to Cobbold, who, thinking it new to science, named i *Distomum ringeri*. In 1883 Baelz, having found specimens in th lungs, named it *D. pulmonale*. In 1890 Otani and Yamagiw proved that it could occur in other parts of the body besides th lungs by finding it in the brain, where it produced symptoms o Jacksonian epilepsy. Stiles and Looss defined its zoologica

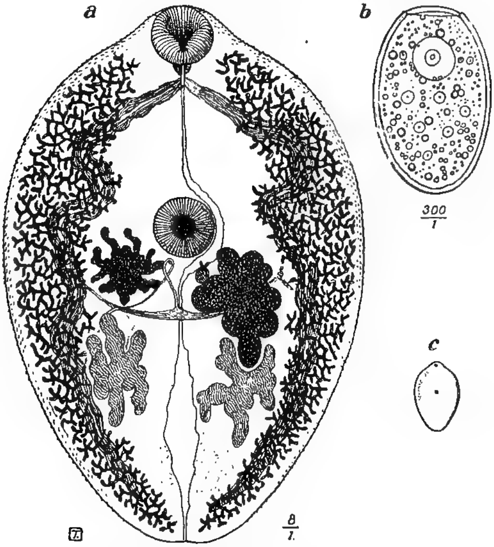

FIG. 141.—PARAGONIMUS WESTERMANI.
(After Looss, from Mense's 'Tropenkrankheiten.')
a, Schematic × 8 ; *b*, eggs × 300 ; *c*, natural size.

position; Ward found it in cats, Railliet in dogs, and Stiles in hogs; while the best description of the lesions caused by it is that by Musgrave in 1907, who found it in the Philippine Islands.

It is very common in Japan, and is found in China, Korea, and North America, a human case being reported from Mexico by Naunyn.

Morphology.—The parasite varies from a reddish-brown to a light slate colour when first removed from the body, but soon becomes greyish on exposure to the air. In shape it is oval, with a somewhat flattened ventral surface, and is capable of slight alterations of its appearance by protruding and retracting its head, and by altering its ventral sucker so that it may appear terminal. The cuticle is covered with scale-like spines, which may be capable of being moved. The oral sucker is spherical and terminal, 0·63 to 0·97 millimetre in diameter. The ventral sucker is situated in the anterior half of the body, and is 0·76 to 1·31 millimetres in diameter. The œsophagus is short, and divides into the two wavy cæca. The genital pore may be indistinct, and is always small, lying close to and behind the ventral sucker. The testes lie about, but not quite on, the same level on each side of the median line just behind the uterus. There is neither a cirrus nor a cirrus pouch. The ovary is opposite and slightly posterior to the uterus, which is visible j posterior to the ventral sucker. The yolk glands lie at the sides, and th branches almost meet dorsally, while ventrally they only extend to intestinal cæca. Laurer's canal is present. The eggs are oval in shape, a reddish-brown to a light yellow in colour, with a length from 0·08 to 0·1 mi metre, and a breadth from 0·052 to 0·075 millimetre. They possess an op culum, and contain the ovum and yolk cells.

The excretory vesicle is well developed, and extends from the phary backwards.

Life-History.—This is not known.

Pathogenesis.—It is the cause of paragonimiasis. (See Cha ter XXXIV.)

Heterophyes Cobbold 1866.

Small Fasciolidæ, with a narrow, movable, anterior portion, a a broader, less movable, posterior portion, which contains t genitalia. Cuticle with scale-like spines; suckers widely separate œsophagus long. Genital pore placed laterally and behind t ventral sucker, and surrounded by genital prominence with chitinous rodle No cirrus pouch. The testes are at t posterior end, and the ovary in a medi position between them. Yolk glands a small, and situated at the sides posteriorl

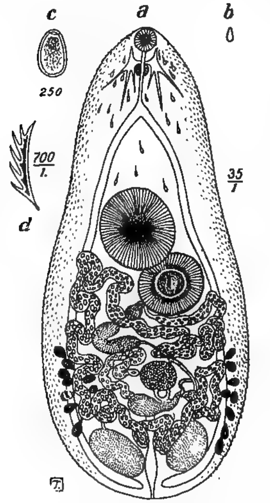

FIG. 142.—HETEROPHYES HETEROPHYES.

(After Looss, from Braun's 'Animal Parasites of Man,' English edition.)

a, Schematic × 35; *b*, natural size; *c*, eggs × 250; *d*, spine × 700.

Habitat.—The intestine.

Heterophyes heterophyes v. Siebold 185

Synonyms.—*Distomum heterophyes* Siebold 1852, *Mesogonimus heterophy* Railliet 1890, *Cœnogonimus heterophy* Looss 1900, *Cotylogonimus heterophy* Braun 1901.

This minute parasite was discover by Bilharz in the intestine of a boy Cairo in 1851, and again a little later, b the third observation was not till 1891 R. Blanchard; since then Looss has fou it in Alexandria and Cairo, where he sa it is not uncommon.

It is also found in dogs and cats in Egy and Japan.

Morphology.—*Heterophyes heterophyes* is pe shaped, very narrow in front, broad behin 2 millimetres in length, by 1 millimetre in bread but can stretch to quite double this length. Cuticle with rectangular scales, a with numerous glands on the anterior ventral surface. Oral sucker 0·1 mi metre and ventral 0·35 millimetre in diameter. Œsophagus relatively lo Intestinal cæca end posteriorly near each other. Testes situated posterior not quite on the same level on each side of the excretory vesicle; ducts j in a large vesicula seminalis, from which a canal unites with the metatren and then discharges into the genital cavity, the pore of which is plac laterally, surrounded by an annular muscular elevation, provided with seventy five to eighty branched chitinous spines, probably intended to help in sexua intercourse.

The ovary lies medianly, and its duct passes backwards to join the receptaculum seminis, which is just in front of the testes.

Here also joins the vitellarian duct of the yolk glands, which also lie laterall in the posterior third of the body. The uterus is coiled throughout th posterior part of the body. The canal of Laurer is present. The eggs hav thick shells, and are 0·03 millimetre in length and 0·017 millimetre in breadth containing a miracidium.

Habitat.—Small intestine.

Pathogenesis.—Perhaps nil, but the parasite is very small, an may therefore be overlooked.

Dicrocœlium Dujardin 1845.

Medium-sized Fasciolidæ, with lancet-shaped bodies, withou spines, and with suckers placed close together. Intestine does no reach the posterior end. Genital pore close behind the pharynx, with the cirrus pouch in front of the ventral sucker, just behind which the testes lie with the ovary in the median line behind them. The uterus lies behind the ovary and testes, extending as far back as the posterior border. The yolk glands are small, and situated in the middle quarter of the lateral areas of the body. The excretory vesicle is tubular. Ova dark brown. Worms live in the liver and gall-bladder, rarely in the intestine.

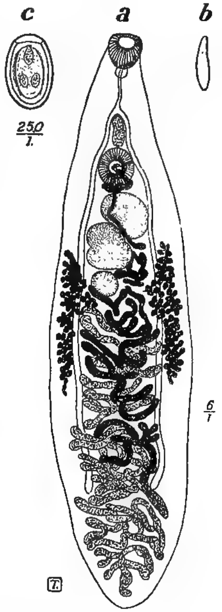

FIG. 143.—DICROCŒLIU LANCEATUM.

(After Looss, from Mense' 'Tropenkrankheiten.')

a, Schematic × 6; *b*, natura size; *c*, eggs × 250.

Dicrocœlium lanceatum Stiles and Hassel 1896.

Synonyms.—*Fasciola lanceolata* Rudolphi 1803, *nec* Schrank 1790; *Distomum lanceolatum* Mehlis 1825; *Dicrocœlium lanceolatum* Dujardin 1845; *Dicrocœlium lanceatum* Stiles and Hassel 1896.

History.—Bucholz appears to have been the first to discover these worms in the gall-bladder in Weimar, and, later, Chabert in the intestines of a girl in France, and Küchner in Weimar. Since then they have been noted in Italy and Egypt. They are found in the bile-ducts of herbivorous and omnivorous animals in Europe, North Africa, Asia, and North and South America.

Morphology.—*Dicrocœlium lanceatum* is a small trematode, measurin 8 to 10 millimetres in length by 1·5 to 2·5 millimetres in breadth. It is pointe in front and narrow behind, so that the widest point is just behind the y glands. Cuticle is smooth ; the oral sucker is terminal, and about the sa size as the ventral (0·5 to 0·6 millimetre). The intestine bifurcates just in fr of the genital pore, which is situate in the median line in front of the ven sucker; behind which the two testes lie, from which the vasa deferentia forwards to form a cirrus lying in a cirrus sac.

The ovary lies behind the posterior testis ; there is a receptaculum sem and a Laurer's canal. The yolk glands lie in the lateral portion of the mid fifth of the body, the posterior portion of which is filled up by the large coi uterus. The eggs are thick-shelled, and yellowish to brown in colour, wit length of 38 to 45 μ and a breadth of 22 to 30 μ.

Life-History.—Not known, but suspicions rest on *Planor marginatus* and land-snails.

Pathogenesis.—No special symptoms.

FAMILY III. MONOSTOMIDÆ.

Trematodes of oval or more or less rounded form, possessing only an o sucker.

Monostomum Zeder 1803.

Monostomum lentis Von Nordmann 1832.

Synonym.—*Festucaria lentis* Moquin-Tandon 1860.

Eight specimens of this parasite were discovered by Von Nordmann the opaque lens of an old woman ; they were only 0·3 millimetre in length.

FAMILY IV. SCHISTOSOMIDÆ LOOSS.

Digenea with separate sexes.

Genus.—*Schistosomum.*

Schistosomum Weinland 1858.

Synonyms.—*Gynæcophorus* Diesing 1858, *Bilharzia* Cobbold 18 *Thecosoma* Moquin-Tandon 1860.

Schistosomidæ with long filiform females and shorter males, wi bodies widened behind, which can curve ventrally to form a *cana gynæcophorus*, in which the female is enclosed. No pharyn Intestinal branches unite at the posterior end of the body. O with spines.

Habitat.—The vascular system.

Species.—*Schistosomum hæmatobium*, *S. mansoni*, *S. japonicum.*

Schistosomum hæmatobium Bilharz 1852.

Synonyms.—*Distoma hæmatobia* Bilharz 1852, *D. capense* Harl 1864, *Bilharzia hæmatobia.*

History.—*Schistosomum hæmatobium* was discovered in the port vein of a man in 1851 by Bilharz in Cairo, and later by Harl in 1864 in a patient from the Cape of Good Hope. Since th it has been found widely distributed through Africa (Egyp Sudan, Tunis, Algiers, West Coast, including the Gold Coast, Ea Coast, and South and Central Africa), which is its endemic cent and in Asia, in Syria, Arabia, Persia, India, Mauritius. On imported cases occur in Ceylon.

Other species are known in sheep, horses, oxen, monkeys, etc.

Morphology—Males.—The male is whitish in colour, and from 12 to 14 millimetres in length, with a greatest width behind the ventral sucker of 1 millimetre. It is really thin and flat, though it may look cylindrical, because the lateral margins are turned ventrally inwards, enclosing a canal, called the 'gynæcophoric canal,' in which the female lies. The whole body is covered with projections tipped with short spines, which enable it to cling to the wall of the bloodvessel. The oral sucker looks ventrally. The ventral sucker is situate near to it. There is no pharynx, but the œsophagus is long and covered with numerous glands, and bifurcates just in front of the ventral sucker into the intestinal cæca, which unite behind the testes into a median trunk. The excretory pore is at the posterior end, situated a little dorsally. There are four to five testes, from which the vas deferens runs to a vesicula seminalis, from which an ejaculatory duct proceeds to the genital pore, situated behind the ventral sucker at the beginning of the gynæcophoric canal.

Female.—The female worm is long, thin, being 20 millimetres in length (*i.e.*, longer than the male) and 0·25 millimetre in breadth (much thinner than the male). Posteriorly it is coloured dark brown, because of the colour of the contents of the intestine. The cuticle is smooth, except in the sucker and at the tail end, where there are large spines. The alimentary canal is much the same as in the male. The ovary is median, and the ovarian duct, taking origin at the posterior end, runs forward to join with the vitellarian duct from the single yolk gland, which lies about the middle of the body. The junction of the two ducts is at first narrow and surrounded by the shell gland, but it soon dilates into the uterus, which runs forwards to end in the genital pore, just behind the ventral sucker. The eggs are bluntly spindle-shaped, yellowish in colour, slightly transparent, and provided with a thin shell, without a lid, but possessing a terminal spine, which may be absent at the posterior end. They measure from 0·12 to 0·19 millimetre in length and 0·05 to 0·073 millimetre in breadth, but vary considerably.

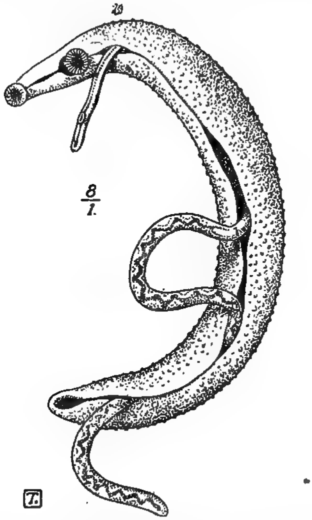

FIG. 144.—SCHISTOSOMUM HÆMATOBIUM.

(After Looss, from Mense's 'Tropenkrankheiten.')

This drawing shows the female worm enclosed in the gynæcophoric canal of the male.

Life-History.—The young immature males and females are only found in the portal system in the liver, which is therefore believed by Looss to be the home of the sporocyst.

When older, the different sexes repair to the portal vein. Looss notes that it is not uncommon to find males alone in that vein, and, further, that they are all of the same age, which he explains by assuming that there are male sporocysts and female sporocysts. Eventually they pair in the portal vein, and now the male carries the female along that vein down the inferior mesenteric vein to the bladder, which is a fairly direct route, but Looss considers that t may be chemically attracted to the bladder, for their journe against the blood-stream, and they are enabled to perform it means of the bristles on the male cuticle.

Looss notes in the females before fertilization, in the portal v and *en route* to the bladder, eggs with lateral spines, but a fertilization eggs with long terminal spines; but the interpretatio this will be dealt with more fully under *Schistosomum mansoni*.

The length of time occupied by the journey is not known, a probably varies considerably. Arrived in the veins of the bladc the real oviposition begins, and Looss is inclined to think that female can push her head (close to which is the genital opening) i the capillaries, and thus lay the eggs directly into these chann where they are held in position by contraction of the capillary u them. Looss thinks that it is probable that the worms may l three years in these vessels, producing during that period la numbers of eggs, which work th way like any other foreign bo into the lumen of the bladder, prc ably by means of the contractic of that organ.

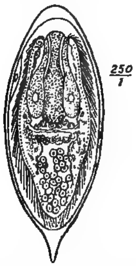

FIG. 145.—EGG OF SCHISTOSOMUM HÆMATOBIUM (× 250).
(After Looss, from Mense's 'Tropenkrankheiten.')

During their journey through t tissues the eggs increase in size frc 0·08 to 0·09 μ in length and 0·03 0·04 μ in breadth in the oötype 0·13 to 0·15 μ in length and 0·04 0·06 μ in breadth in the urine, wh the embryo develops, so that wh they are voided in the urine th contain a well-developed mira dium; but during this journey ma die and become calcified. It is n known how long an egg must take before it escapes in the urine, b Looss points out that even the presence of an egg with a tr miracidium is no evidence that the parent worms are alive. The eggs will simply die, unless they gain access to water, in which th hatch, and the ciliated miracidium escapes and swims about.

In the so-called body cavity of this miracidium there are germin cells the development of which has been traced in *Fasciola hepatic* One would therefore assume that the miracidium required anoth host—*e.g.*, an invertebrate, possibly a mollusc, crustacean, a insect, or a vertebrate, perhaps a fish—but the careful observatio of Looss in the Nile Valley have not established its entry into an of these animals. Moreover, it does not live long in water, thirt to forty hours being the greatest period.

Therefore Looss has come to the conclusion that man is th intermediary host. He further points out that it cannot be vi the stomach, for a solution of 1 in 1,000 hydrochloric acid kills the instantly; therefore he is forced to the conclusion that they enter th body viâ the skin while the people are bathing. In this he is supported by the habits of the people, who work in the fields standing in liquid mud, and bathe in companies in canals with slow-flowing water, or in pools which may possibly have become infected by persons urinating into the water.

From the skin Looss thinks that they work their way to the liver, where the further development is gone through.

But the worms do not always remain in the bladder, it being possible for them to work their way to the rectum by means of communicating veins, when the eggs escape with the fæces.

Moreover, Looss thinks that sometimes they may miss the direct route to the bladder, and get by accident into the veins of the rectum.

Further, it appears that the young immature worms, instead of entering the portal system, may get into the hepatic venous system, for they have been seen by Kartulis in the vena cava and by Symmers in the lung.

Eggs laid in the portal system may be carried to the liver by the blood-stream. In this organ they may lodge, and work their way into the hepatic venous system, and thus into the lungs or into the bile-ducts, and so to the fæces and to the exterior of the body. It must be admitted that Looss's views do not obtain universal support, and that several authorities believe that a cycle analogous to *Fasciola hepatica* will some day be found.

Pathogenesis.—*Schistosomum hæmatobium* is the cause of one form of urinary schistosomiasis (*vide* Chapter XLIX.).

Schistosomum mansoni Sambon 1907.

It has long been known that in cases of schistosomiasis two kinds of eggs can be seen—one with a terminal spine when the urinary system is affected, and the other with a lateral spine when the intestine is affected. In 1903 Manson noted that in a case from the West Indies in which the disease attacked the rectum, and not the bladder, the eggs all had lateral spines, and he therefore suggested that these eggs might possibly belong to a separate species of *Schistosomum*.

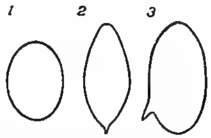

Fig. 146.—Outlines of the Eggs of (1) S. japonicum; (2) S. hæmatobium; (3) S. mansoni.

(After Sambon.)

In 1907 Sambon created a new species, *Schistosomum mansoni*, for the following reasons:

1. Lateral spined eggs are never found in the urine, but only in the fæces, and never occur in the bladder, only in the rectum and liver.

2. The egg is oval in shape, with a lateral spine, while that of *S. hæmatobium* is oblong and lanceolar in shape, with a terminal spine, and that of *S. japonicum* oval or roundish, without a spine.

The lengths and breadths are different: *S. mansoni*, 112 to 162 μ by 60 to 70 μ; *S. hæmatobium*, 110 to 120 μ by 46 to 50 μ; *S. japonicum*, 75 to 90 μ by 53 to 75 μ.

3. The males are apparently similar, but the females hav difference in the genital tract, which has been described by Frits and when mature contain lateral-spined ova in the uterus.

4. The geographical distribution of *S. mansoni* and *S. hæmatobi* were different. *S. hæmatobium* is alone found in the Cape; *S. mans* is the only species in the West Indies and in South America.

Looss has challenged these statements, maintaining that the lateral-spi eggs are the products of unfertilized females, and pointing out that Bilharz l noted the presence of a lateral-spined ovum in the anterior portion of the ute and terminal spined ova in the posterior port of the same female, which he—Looss—him believes that he has seen. Looss thinks tha is possible for only females to occur in a pers and they, not having the muscular strength the long journey against the blood-stream to bladder, are thus driven into side-channels reach the bowel. These unfertilized females only produce lateral-spined ova, which, be shed all the way along, are carried to the li Thus no terminal-spined ova will ever appe but only lateral-spined ova, which will be voi by the fæces.

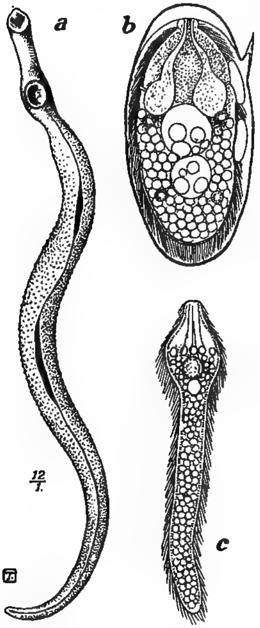

FIG. 147.—SCHISTOSOMUM MANSONI.
(After Holcomb.)
a, Male; *b*, egg; *c*, larva.

He answers Sambon's points in the follow manner:

1. The lateral-spined ova do not represent eggs of a new species of *Schistosomum*, but mer those produced by unfertilized females of *hæmatobium.*

2. Terminal-spined ova occur frequently in fæces and rectum.

3. The difference in the eggs is simply due the fact that they are products of unfertili or fertilized females, and in all cases where terminal-spined ova are found the lateral also be found, especially if the liver be examin

4. The description of differences in the fem generative organs as given by Fritsch is wron

5. Straight-spined ova in the urine h been found in the West Indies, as recorded Holcomb.

6. Man being in all probability the int mediary host, there are no bounds to geographical distribution of *S. hæmatobium.*

These criticisms of Looss have been answe by Sambon, who has also been supported Ward. And quite recently da Silva has described the adult worms, wh show differences from *S. hæmatobium.*

Notwithstanding Looss's great authority, we consider *S. mansoni* to b different species from *S. hæmatobium.* We base our opinion especially the experience of one of us who while in Equatorial Africa observed numer cases of rectal bilharziosis, all with lateral-spined eggs, and never cases vesical bilharziosis. It would be difficult to imagine that all those patie should harbour unfertilized females.

The morphology of the adult worms has been described by P. Silva of Bahia as follows:

Morphology—*Males.*—The male measures 12 millimetres in length 0·448 millimetre in breadth in the middle. The ventral sucker is 0·540 mi metre behind the oral sucker.

The anterior end shows six sexual masses composed of testes and semina vesicles. The posterior end is tapering. The spinous papillæ are not s marked as in *S. hæmatobium.*

Females.—The female worms measure 14·5 to 15 millimetres in length b 0·168 millimetre in breadth in the middle. The distance between the tw suckers is 0·224 to 0·252 millimetre. It is thickest in the middle, and taper to each extremity. The anus opens 0·336 millimetre in front of the tip of th tail. The oviduct is much shorter than in *S. hæmatobium,* and enters th vitelline ducts after only a short turn. The uterus contains laterally spine eggs. The eggs measure 146 μ by 62 μ, with 18 μ as the length of the spiculum The miracidium escapes by a transverse rupture of the shell, and measure 153 μ by 72 μ.

Pathogenicity.—It is the cause of intestinal schistosomiasis (*vid* Chapter XLVI.).

Schistosomum japonicum Katsurada 1904.

Synonym.—*Schistosomum cattoi* Blanchard 1905.

History.—For several years an endemic disease, characterized b enlargement of the liver and spleen, fever, diarrhœa with mucu and blood in the motions, associated with ascites and cachexia an extreme weakness, had been observed in the provinces of Yamanash and Hiroshima of Central Japan and Saga of Kinshu. Eggs con taining a miracidium were to be found in the liver and other organs

Katsurada then examined cats in the neighbourhood, and foun numerous *Schistosoma* in the portal veins of two cats in the provinc of Yamanashi, in which there were eggs exactly similar to thos found in the above-mentioned disease. Catto a little later found the same parasite in a Chinaman from the province of Fukien Recently Logan has found it in a Chinaman from the province o Hunan, Nicols in a case from the Philippines, and Manson and Sambon in cases from China and South Africa.

Morphology.—In general appearance the parasite resembles *S. hæmatobium* but is smaller. Male, 7 to 12 millimetres in length, 0·53 millimetre in breadth females, 8 to 12 millimetres in length, 0·4 millimetre in breadth. The ventra sucker is relatively larger than the oral. The male worm has no tubercles. The eggs are oval, yellowish-brown in colour, without operculum or spine, 60 to 90 μ in length and 30 to 50 μ in breadth. Catto points out that thes eggs might be mistaken for those of *Agchylostoma duodenale.*

Pathogenesis.—The parasite is the cause of one form of schistosomiasis—viz., katayama disease (*vide* Chapter XXXIV.).

Christophers and Stephens' Schistosomum.

Christophers and Stephens have described a *Schistosomum* egg which differs from the usual descriptions, and which therefore may belong to a new and as yet unknown species or genus; but it was found with ordinary *S. hæmatobium* eggs, and may therefore be an abnormality. The egg was found in Madras; it was of an elongated, spindle shape, with a long snout-like process extending from the broader end (205·2 μ by 53·2 μ).

New Schistosomum.

Recently Salomone and Belli found portions of a worm which they think may be a new *Schistosomum* in a patient suffering from hæmaturia contracted in Brazil.

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CHAPTER XV

BIOLOGICAL CAUSES OF DISEASE (*continue*
—CESTOIDEA

Cestoidea—History—Morphology—Life-History—Habitat—Classificatio
Description of species found in man—References.

CESTOIDEA Rudolphi 1808.

PLATYHELMIA without alimentary canal in any stage of the life cy with segmented body, in which the epidermis, which has sunk i the parenchyma, secretes a thick cuticle. Lime-secreting cells developed in greater or less number, and form calcareous concretio Organs of fixation of a variable character are developed. T habitat of the adult worm is typically the intestine, and that of larval form some other part of the body, often of another host.

History.—It is believed that cestodes were known to the ancien and that the reason why Moses, who figures largely in the history Tropical Medicine, forbade the Israelites to eat pigs and su animals, was because of the parasites known to exist in their fles

Aristotle knew the proglottides of tapeworms, and as early 1592 *Tænia* was distinguished from *Bothriocephalus*. Tyson (16 discovered the head of the tapeworm of a dog. Redi (1687-17 came to the conclusion that *Cysticerci* were animals, and Ze (1800) formed them into a separate group, *Cystici*; but Küch meister in 1851 proved by feeding experiments that these were o the larvæ of tapeworms, and that, as a rule, two different kinds animals were required as hosts in order that the life cycle mi take place.

Leuckart, Braun, Looss, Sonsino, Grassi, Blanchard, Von Linst Lühe, Stiles, Sambon, and Leiper may be mentioned as investigat who have greatly improved our knowledge of these parasites.

Morphology.—There are two groups of cestodes, one called the Cestoda containing genera with only a single segment, and another Cestoda, in restricted sense of the word, which includes all forms possessing a scolex segments. It is with this latter group that we are now concerned.

The true cestodes are easily recognized by their band-like segmented bo which is usually of a white colour. They are broad and large posterio becoming narrower and narrower till the place is reached where they attached to the intestinal wall. This anterior end is called the 'scolex,' w the segments are called 'proglottides.' The scolex is divisible into a broa anterior portion called the head, and a narrower posterior portion, the ne

The head is provided with muscular suckers, which keep it attached to the mucous membrane of the bowel. Often there are also hooks present on some part of the head, not infrequently on an anterior projection called the rostrum. The neck is constricted, and shows posteriorly faint rings indicating the commencement of new segments, which are always formed from the neck.

Behind the head come the proglottides, the youngest being situated anteriorly and the most fully developed posteriorly. Their number is very variable, and their size increases from before backwards. They contain the male and female sexual organs.

The whole surface of the worm is covered by a thick, non-chitinous cuticle, said to contain a quantity of lime salts, under which lies a basal membrane; beneath this come the cuticular muscles, and then the cortical parenchyma, in which lie the sunken epithelial cells, nerve cells, sense organs, excretory cells, etc. Among these cells are peculiar calcareous corpuscles, varying from 3 to 30 μ in diameter, and having essentially the structure of a fat cell—that is to say, they are composed of concentrically deposited calcareous material enclosed in a cell with a nucleus at one side. These corpuscles are highly characteristic of a Cestode. The calcareous matter is composed of 79 per cent. organic matter and 21 per cent. of lime salts, in the form principally of the carbonate, but also of an albuminate and a urate. Their function is not understood; perhaps it is skeletal, perhaps protective.

In the cortex come the longitudinal muscles, beneath which are the transverse muscles, which enclose a central area of the parenchyma called the medullary layer, and therefore separate cortical from medullary layers.

There is no alimentary canal, and the excretory system consists of flame cells with anastomosing capillaries emptying into a dorsal and ventral collecting tube on each side of the body, which run from the scolex to the last proglottis, where they open to the exterior. In the originally posterior proglottis there is a pear-shaped excretory vesicle in the middle of the posterior edge, but this arrangement is lost when this proglottis drops off, and then the tubes open as a rule separately on the last proglottis. The nervous system consists of one ganglion in the scolex and two nerve cords. The generative organs gradually develop in the proglottides as they grow older, the youngest having no trace of them. With the exception of the end portions, these organs lie in the medullary layer of the body.

The male organs, which are the first to reach maturity, usually consist of numerous follicular testes scattered over the dorsal portion of the medullary layer, but may be consolidated into one to three glands. The efferent ducts from these unite about the middle of the proglottis into a vas deferens, which after a wavy convoluted course, enters a cirrus pouch and terminates in the genital atrium near the vaginal orifice.

The female reproductive organs consist usually of two ovaries, which lie near the ventral surface of the medullary layer, from which a common oviduct runs to join with the spermatic duct, which, after travelling a certain distance, is dilated to form a receptaculum seminis, and continued as the vagina to the female opening in the genital atrium. After the junction with the spermatic duct, the oviduct is joined by the common duct of the yolk or vitellogene gland or glands, and then, forming the oötype, receives the ducts of the shell gland, and passes on to enter the uterus. This is usually a blind tube, but may open by a special aperture on the same or the opposite surface to that on which the genital atrium is found.

When the uterus becomes laden with eggs, it is apt to alter its appearance and become branched, and grows, filling up the proglottis, while the male generative organs atrophy and disappear.

Life-History.—The proglottis can fertilize itself with or without the use of the cirrus, or different proglottides may fertilize one another. In any case the receptaculum seminis receives the spermatozoa, which travel down the spermatic duct, and, meeting the ovum, fertilize it. The fertilized ovum now obtains its yolk (vitellus) and its shell, and then passes into the uterus, from which it may esca by the uterine orifice when there is one, or not until the proglottis destroyed.

Development usually begins in the uterus. An egg is as a rule o in form, enclosed in a brown or yellow shell with or without operculum. This shell contains food yolk and the developi embryo, whose cells form two membranes—an outer in contact w the shell, and an inner in contact with the embryo.

The outer envelope and the shell are soon lost, and when t embryo appears in the fæces it is surrounded by its inner envelo the embryophore, and has developed six hooks. In this stage development it is called an onchosphere.

It will therefore be evident that the so-called egg as seen in t fæces is not an egg at all, but the onchosphere with its embryo envelope, which in certain species may be ciliated.

When the onchosphere enters the alimentary canal of a new ho generally of a different class from the original host, it throws off envelope, and works its way into the tissues by its hooks until arrives in some suitable organ, when it throws off its hooks, encys and forms either a little bladder-like cyst, from the wall of which t scolex develops (the whole being called a '*Cysticercus*'; if the cyst small, it is called a 'cysticercoid'; or if it has a caudal appendix 'cercocystis'), or it develops directly into the scolex without t intervention of a cyst, forming a plerocercoid (πλήρης, full; κέρκ a tail). These wanderings of the onchosphere in search of a suita resting-place may produce unpleasant symptoms if there are number of parasites. The time occupied in the transformation of onchosphere into a *Cysticercus* varies, being from two to six mont or longer.

With but rare exceptions the *Cysticercus* does not develop furt until it enters another and different host, though some, like *Hyme lepis murina*, which has its larvæ in the villi and its adults in t intestine of the rat, infest only one host.

Often the *Cysticercus* is found in a herbivorous animal, while t tapeworm occurs in a carnivorous or omnivorous animal. Infecti is direct by feeding, for in the alimentary canal the cyst dies off, a leaves the scolex, which develops in the course of a few weeks i an adult tapeworm, whose span of life appears to be about a ye but may be much more or much less. An example is, *Cysticer fasciolanus* of the mouse which becomes *Tænia crassicollis* in the c Abnormalities are often met with in the segments.

Habitat.—As a rule the adult lives in the alimentary canal usua of a vertebrate, but they may be found in the liver and pancre They are capable of active movements during life. Food is obtai by osmosis from the contents of the alimentary canal.

Classification.—The classification followed is that of Montice given by Braun in Bronn's 'Klassen und Ordnung des Thierreichs

The *Cestoidea* Rudolphi 1808 are divided into *Cestoidaria* Mo celli 1892, which are Cestodes consisting of a single segment c taining a single set of reproductive organs, and *Cestoda sensû strictû* Monticelli 1892, which are the typical cestodes with a scolex and segments. The subclass Cestoda are divided into orders as follows :

SUBCLASS CESTODA SENSÛ STRICTÛ Monticelli 1892.

Synonyms.—*Pollaplasiogonei* E. Blanchard, *Cestodes digénèses* van Beneden, *C. polyzoa* Lang.

Definition.—Cestodes in which the adult worm consists of a scolex and proglottides.

ORDER I. PSEUDOPHYLLIDEA *Carus* 1863.—**Synonyms.**—*Bothriocephaloidea.*—Scolex armed or unarmed, with two usually slightly developed, groove-like suckers, with three genital orifices. Vitellaria situated laterally. Eggs with or without a lid.

ORDER II. TETRAPHYLLIDEA *Carus.*—Scolex armed or unarmed, with four very motile pedunculated or sessile bothridia, or with four round suckers ; no uterine orifice ; cirrus and vagina open at the sides. Vitellaria situated laterally.

ORDER III. CYCLOPHYLLIDEA *Van Beneden.*—Scolex with four suckers, between which there is an apical rostellum with or without hooks ; segmentation distinct ; no uterine orifice ; vitellogene gland single, placed behind the ovary. Eggs without lids.

ORDER IV. DIPHYLLIDEA *Carus.*—Head stalk armed with hooklets, with scolex, rostellum, and two bothridia.

ORDER V. TRYPANORHYNCEA *Diesing.*—Scolex with two or four bothridia, and four retractile armed rostella.

The only orders which contain parasites found in man are I. and III.

CESTODES IN MAN.

The cestodes which are found in man may be classified as follows :

Order and Family.		Subfamily.	Genus and Subgenus.		Species.
Pseudophyllidea	Dibothrocephalidæ	Dibothriocephalinæ	Dibothriocephalus		1. D. latus.
					2. D. cordatus.
					3. D. parvus.
			Diplogonoporus		4. D. grandis.
			Sparganum		5. S. mansoni.
					6. S. proliferum.
					7. S. baxteri.
		Ligulinæ	Braumia		8. B. jassyensis.
Cyclophyllidea	Tæniidæ	Dipylidiinæ	Dipylidium		9. D. caninum.
			Hymenolepis	Hymenolepis	10. H. nana.
					11. H. diminuta.
				Drepanidotænia	12. H. lanceolata.
		Davaineinæ	Davainea		13. D. madagascariensis
					14. D. asiatica.
		Tæniinæ	Tænia	Tænia	15. T. solium.
				Tæniorhynchus	16. T. saginata.
					17. T. africana.
					18. T. hominis.
					19. T. philippina.
				Subgenus ?	20. T. confusa.
					21. T. bremneri.
			Echinococcus		22. E. granulosus.
					23. E. multilocularis.

Two tapeworms are not included in this list—*Tænia* (Tær *teniæformis* Bloch 1750, a tapeworm found in cats, and *T.* (Tær *pisiformis* Bloch 1780, a tapeworm found in rabbits—because definite evidence exists that man has ever been infected by them

At the time of writing man alone is known to be the host of adults of the following worms : *Tænia solium, T. saginata* (there probably no doubt about this), *Dibothriocephalus parvus, Hyme lepis nana* (?), *Davainea madagascariensis, D. asiatica, T. africa T. hominis, T. philippina, T. confusa, T. bremneri.* Other ho may yet be found.

The following are only occasional parasites in man : *Dibothr cephalus latus* (true host the dog), *D. cordatus* (true host the seal a walrus), *Hymenolepis diminuta* (true host the rat and mous *Drepanidotænia lanceolata* (true host ducks and geese).

Therefore in man there is the question of intestinal tæniases to considered. But cysticerci may also develop in man from *T. soli* and *Echinococcus granulosus* and *multilocularis*, and from the spec of *Sparganum*, causing somatic tæniases. Both these affectio will be considered later, as will the treatment.

It must be noted that the cysticercus of *T. saginata* and of *T. hya tigena* (a worm very like *T. solium*, and common in dogs) are n included, as it is very doubtful whether they have ever been fou in man.

Cysticercus acanthotrias Weinland 1858 is the same as *C. cellulo* —*i.e.*, the larva of *T. solium.*

The following tables, modified from Stiles, may be of help enabling a human cestode to be recognized, as they give the mea of recognition of the genera, and the species of *Tænia*, as determin by the head or the segment, and also a scheme for recognizing t eggs.

Table of Genera.

A. Head with two elongated or slit-like suckers ; uterus forms a rosett genital pores ventral. (*Dibothriocephalidæ.*)

I. *Tapeworms.*—Single set of genital and uterine pores present medium ventral line. (*Dibothriocephalus.*)

Double set of genital and uterine pores present in ventr submedium lines. (*Diplogonoporus.*)

II. *Plerocercoids.* (*Sparganum.*)

B. Head with four cup-shaped suckers ; uterus does not form a rosett genital pores lateral. (*Tæniidæ.*)

I. Large forms, ripe segments 9 to 35 millimetres long. Uterus medi with lateral branches. (*Tænia.*)

II. Smaller forms, ripe segments up to 7 millimetres long.

(*a*) Genital pores single, rostellum with no more than two hook

(1) Suckers not armed. Three testes in each segme (*Hymenolepis.*)

(2) Suckers armed with hooks, 15 to 50 testes in ea segment. (*Davainea.*)

(*b*) Genital pores double, rostellum with several rows of hook (*Dipylidium.*)

Table of the Species of Tænia found in Man.

A. SPECIMEN IS A TAPEWORM.

Head Characters.

I. Head armed with hooks. Subgenus : *Tænia*. Species : *T. solium.*

II. Head unarmed. Subgenus : *Tæniorhynchus.*

(1) Circular ring around head behind the suckers, which are directed postero-anteriorly. (*T. hominis.*)

(2) Without circular ring.

(*a*) Head cuboid, 1·5 to 2 millimetres in diameter ; suckers, 0·7 to 0·8 millimetre in transverse diameter. (*T. saginata*).

(*b*) Head small, 1·38 millimetres broad, 1·03 millimetres thick, 0·47 millimetre long, suckers, 0·63 millimetre in transverse diameter. (*T. africana.*)

(*c*) Head small cuboid, 1 to 1·5 millimetres in diameter ; 0·75 millimetre thick, and 1 millimetre long. Suckers, 0·34 to 0·37 millimetre in transverse diameter. (*T. philippina.*)

III. Head not known. (*T. confusa, T. bremneri.*)

Segment Characters.

I. *Segment Longer than Broad.*

(*a*) Only in the last 100 segments. (*T. saginata.*)

(*b*) In the last half of the worm. (*T. solium.*)

(*c*) In nearly the entire worm. (*T. confusa.*)

(*d*) Always. (*T. africana.*)

(*e*) Known segments very large, 28·6 by 8·5 millimetres on an average. (*T. bremneri.*)

(*f*) Unknown. (*T. hominis.*)

II. *Segment Broader than Long.*

Except in the terminal segments, which are equilateral or slightly longer than broad. (*T. philippina.*)

B. SPECIMEN IS A CYSTICERCUS.

I. Small bladder-worm with one scolex. (*Tænia.*)

(*a*) Head armed. (*T. solium.*)

(*b*) Head unarmed (very rare, if ever present). (*T. saginata.*)

II. Large bladder-worm with brood capsules, inside which are the scolices : (*Echinococcus.*)

C. SPECIMEN IS AN EGG.

I. With an operculum. (*Dibrothriocephalidæ.*)

68 to 71 μ × 45 to 50 μ. (*D. latus.*)
75 to 80 μ × 50 μ. (*D. cordatus.*)
63 × 48 μ to 50 μ. brownish. (*D. grandis.*)

II. Without an operculum and with a six-hooked embryo. (*Tæniidæ.*)

Egg with a thick, radially-strated, inner shell or embryophore. (*Tæniinæ.*)

(*a*) Embryophore round or oval, 39 × 33 μ. Africa. (*T. africana.*)

(*b*) Embryophore oval, whitish to yellow, 39 × 30 μ. America. (*T. confusa.*)

(*c*) Embryophore, 38 × 30·4 μ. Africa. (*T. bremneri.*)

(*d*) Embryophore oval, 35 to 41 μ × 26 to 35 μ. Philippines. (*T. philippina.*)

- (*e*) Embryophore, ovoid, rusty brown, 35 to 40 μ × 20 to 3
  Cosmopolitan and common. (*T. saginata.*)
- (*f*) Embryophore almost round; brown; 31 to 36 μ. Not
  common in the tropics. (*T. solium.*)
- (*g*) Egg and embryophore unknown. Asiatic Russia.
  hominis.)

III. Egg with a thin, membranous inner shell.,

- (1) *Not in Capsules.* (*Hymenolepis.*)
  - (*a*) Egg oval or globular, with two distinct membranes—ou
    30 to 60 μ, inner, 16 to 34 μ—mammillate projection
    each pole. (*H. nana.*)
  - (*b*) Egg round or oval; outer membrane, 54 to 86 μ; yellowi
    may be radially striated; inner membrane, 24 to 40 μ
    20 to 35 μ, with not very evident mammillate project
    at each pole. (*H. diminuta.*)
  - (*c*) Egg oval or spherical; outer membrane, 50 to 100 μ × 35
    100 μ; inner membrane, 30 to 40 μ × by 25 μ; occasiona
    polar papillæ; very rare in man. (*H. lanceolata.*)
- (2) *Egg in Capsules.*
  - (*a*) Eight to twenty eggs in a capsule; egg spherical, 43 to 5
    (*Dipylidium caninum.*)
  - (*b*) One to three eggs in a capsule, with calcareous corpuscl
    Eggs with two shells and two mammillate projectio
    onchosphere, 8 μ. (*Davainea madagascariensis.*)
  - (*c*) Egg capsules without calcareous corpuscles; mature eggs
    observed. (*D. asiatica.*)

ORDER I. PSEUDOPHYLLIDEA Carus.

This order has three families: (1) Dibothriocephalidæ; (2) Ptychobothriid
(3) Amphitretidæ. The first only contains human parasites.

FAMILY DIBOTHRIOCEPHALIDÆ.—Pseudophyllidæ, with variously develo
suckers, and a uterus which forms a rosette. Eggs with opercula. There
two subfamilies with species found in man: (1) Dibothriocephalin
(2) Ligulinæ.

SUBFAMILY I. DIBOTHRIOCEPHALINÆ.—The suckers or bothria are more
less definite slit-like furrows. Proglottides distinct, and drop off in grou
Genus 1. *Dibothriocephalus*; Genus 2. *Diplogonoporus*; Genus 3. *Sparganu*

Dibothriocephalus Lühe 1899.

Synonyms.—*Bothriocephalus pro parte* Rudolphi 1819, *Dibothrius pro pa*
Rudolphi 1819, *Dibothrium pro parte* Diesing 1850.

Dibothriocephalinæ, with a more or less elongated, unarmed scolex w
flat suckers cutting deeply into the head. Single genitalia in each proglot
(1) *Dibothriocephalus latus*; (2) *D. cordatus*; (3) *D. cristatus*; (4) *D. parvus*

Dibothriocephalus latus L. 1748.

Synonyms.—*Tænia lata* L. 1748, *T. vulgaris* L. 1748, *Bothriocephalus la*
Bremser 1819, *T. grisea* Pallas 1796, *Dibothrium latus* Diesing 1830,
membraneacea Pallas 1781, *B. cristatus* Davaine 1874, *T. tenella* Pallas 17
B. balticus Küchenmeister 1855, *T. dentata* Batsch 1786, *B. latissimus* Bu
1886.

History.—This tapeworm has long been known in Europe, especially
French Switzerland and the Baltic provinces, Germany, and in many ot
parts. It is, however, well known in Asia, Turkestan, and Japan; in Afr
about the Lake N'gami, in Madagascar, and in North America.

It occurs in man and dogs and cats.

Morphology.—It is about 9 metres in length, with some 3,000 to 4,200 s
ments; colour yellowish-grey. Scolex elongated, almond-shaped; 2·5 mi

metres in length, with two deep laterally placed suckers. Neck very narrow, and of variable length.

Proglottides very broad (10 to 20 millimetres), breadth being greater than the length; postero-lateral angles project. Testes situated dorsally; vas deferens has a vesicula seminalis and a cirrus sac, which opens dorsally. Vaginal opening directly behind this, leading into a receptaculum seminis. Yolk glands in pairs, shell gland behind, ovaries on each side of the median line behind. Uterus arranged in a rosette, with four to six convolutions, and possesses its own separate opening. The genital orifices are two in number; a transverse slit for the cirrus pouch and the vagina, and a posterior roundish opening for the uterus. Calcareous bodies present. The brown eggs are oval, 68 to 71 μ in length, and 45 μ in breadth, with an operculum.

Life-History.—The egg remains undeveloped for a longer or shorter time according to circumstances, and eventually a six-hooked onchosphere, enclosed in a ciliated embryophore, escapes through the lid opening, and then gets into certain fish, particularly *Esox lucius* (pike), *Lota vulgaris* (Miller's thumb), *Perca fluviatilis*, *Salmo umbla*, *Trutta vulgaris*, *T. lacustris*, *Thymalis vulgaris*. *Coregonus lavaretus*, *C. albula* and *Onchorhynchus perryi*, in the muscles of which it becomes a plerocercoid by losing its cilia and hooklets and elongating.

When these fish are eaten, the plerocercoids quickly develop into the tapeworm, eggs appearing in the fæces in some twenty-one to twenty-four days.

Habitat.—Man, dog, cat, and fox.

Pathogenesis.—It produces a severe form of anæmia, together with fever (99° to 104° F.) in some cases, and a quick pulse, which is supposed to be due to the action of a toxin.

Dibothriocephalus cordatus R. Leuckart 1863.

Synonym.—*Bothriocephalus cordatus* R. Leuckart.

The parasite is commonly found in the seal, the walrus, and the dog in Greenland and Iceland. It may infect man.

Morphology.—The principal features are the short, broad, heart-shaped head with the grooves on the flat surface, the absence of the neck, and the length only 1 to 1¼ metres. Uterine rosette, with six to eight loops. Eggs with lids 75 μ in length by 50 μ in breadth.

Dibothriocephalus parvus Stephens 1907.

This parasite was found by Elkington in Tasmania in 1906 in a Syrian, aged thirty-seven, who had not long arrived from his native country.

Morphology.—Scolex not known.

Proglottides with clearly defined, central, uterine rosette, with four to five loops on each side of the median line; largest segment, 5 by 3 millimetres. Genital atrium 0·4 to 0·5 millimetre behind the anterior margin; uterine opening same distance behind the genital atrium. Calcareous bodies were not seen. Eggs, 59 by 40 μ.

Diplogonoporus Lönnberg 1892.

Synonym.—*Krabbea* R. Blanchard 1894.

Bothriocephalinæ with short scolex, powerful suckers, no neck, and two sets of genitalia side by side in each proglottis.

Diplogonoporus grandis R. Blanchard 1894.

Synonym.—*Bothriocephalus* (?) Ijima and Karimoto, *Krabbea* R. Blanchard.

So far this parasite has only been observed twice in Japanese—in Hioyo, Japan.

Morphology.—Scolex unknown. Proglottis, 1·5 millimetres broad in front, and 2.5 millimetres broad behind; very short, only 0·45 millimetre. Two ventral grooves on either side of the median line with the genital pores. Uterus with few loops. Eggs brown; thick shells, 63 to 48 μ in length and 50 μ in breadth, with opercula.

Sparganum Diesing 1850.

Larval stages of Dibothriocephalidæ which have not reached a stage in their development at which they can be determined generically. It is an artificial group: *Sparganum mansoni*, *S. proliferum*, *S. baxteri.*

Sparganum mansoni Cobbold 1883.

Synonyms.—*Ligula mansoni* Cobbold 1883, *Bothriocephalus liguloides* R. Leuckart 1886, *Dibothrium mansoni* Ariola 1900.

This larva was found by Manson while making a post-mortem on a Chinaman in Amoy, lying under the peritoneum near the kidneys and over the iliac fossæ; he also found one free in the pleural cavity. Scheube discovered another specimen in the urethra of a Japanese, and Sonsino a third in an Egyptian jackal.

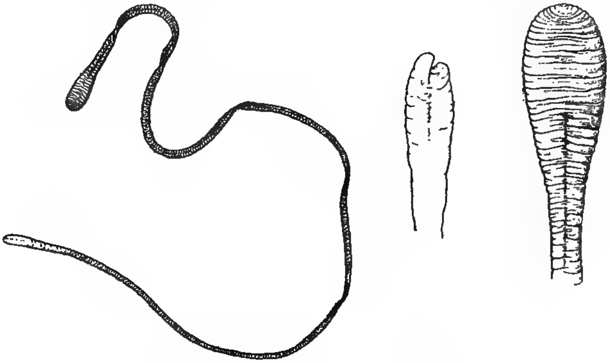

FIG. 148.—SPARGANUM BAXTERI SAMBON FROM MAN.
(After Sambon.)

Morphology.—Long, white, ribbon-shaped parasites, with feeble movements. No head or definite structure visible. Length, 30 to 35 centimetres; breadth, 3 to 12 millimetres. At the broader end there is a sort of papilla. There is no reproduction by fission.

Sparganum proliferum Ijima 1905.

Synonym.—*Plerocercus proliferum* Ijima 1905.

In 1905 Ijima found this worm in a woman living near Tokio, and in 1907 Gates found the same or a similar worm in a man in Manatee, U.S.A., and recently Sambon has found a parasite very much resembling *S. proliferum* in Cook's tree-boa (*Corallus cookii*).

Morphology.—The larva, which lies enclosed in a cyst, may attain 1 to 12 millimetres in length by 2·5 millimetres in breadth. The head at the narrow end is motile, and capable of evagination and invagination. It shows an apical depression, which perhaps serves as a sucker, but there are no true suckers or other organs of attachment.

Calcareous spherical corpuscles can be found anywhere, except in the head. No genitalia are to be seen, but there is a good muscular and excretory system and food-reserve bodies. It can multiply by transverse division, and supernumerary heads may become independent, and may assume bizarre and irregular shapes. The adult is unknown.

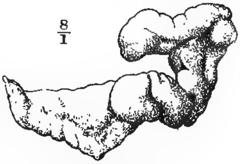

FIG. 149.—SPARGANUM PROLIFERUM IJIMA. (After Stiles.)

Habitat.—It lives in the subcutaneous tissue and elsewhere in man.

Pathogenesis.—It produces nodules in the skin and fascia between the muscles and in the abdominal cavity. Associated with these nodules there may be considerable swelling of the integument, and, in fact, a condition not unlike elephantiasis may arise. Also there may be acne-like spots all over the body causing itching, which may lead to the escape of a worm from the spot. When a nodule is cut open, a cyst is found containing one or two worms, either filled with a watery fluid, or with a jelly or slime like substance. Apparently after weeks or months the cyst-wall may become firm and thick, and encapsulate the worms. This condition may last for years, and apparently can kill the victim, who may be literally eaten up of worms.

Sparganum baxteri Sambon 1907.

This Dibothriocephalid larva was found by Baxter in an abscess in the thigh of a Masai in German East Africa.

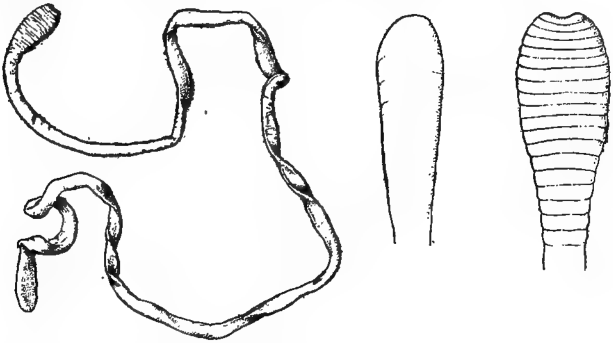

FIG. 150.—SPARGANUM BAXTERI SAMBON FROM BITIS NASICORNIS. (After Sambon.)

Sambon has recently found a parasite exactly like it in the body cavity of the horned viper (*Bitis nasicornis*) from Africa.

Morphology.—It has a long unsegmented body, 15 centimetres in length and 1 millimetre in breadth, with numerous irregular transverse folds, and a distinct longitudinal groove on the ventral surface. Anterior extremity is 2 millimetres broad, with a completely invaginated head; posterior extremity, 1·2 millimetres broad, with a shallow medium slit.

SUBFAMILY 2. LIGULINÆ.

Quite recently Lear has described a new tapeworm in man which is referred to the Ligulinæ, but which requires a new genus, and is called *Braumia jassyensis* Lear 1908.

ORDER III. CYCLOPHYLLIDEA Van Beneden.

There is only one family with human parasites.

FAMILY TÆNDIIÆ Ludwig 1886.

Scolex globular or pyriform, with unarmed suckers, and an armed or unarmed rostellum. Vagina posterior to the cirrus. Mostly parasitic in mammals. Larval stage a cysticercus or cysticercoid. Subfamily 1. Dipylidiinæ; Subfamily 2. Davaineiinæ; Subfamily 3. Tæniinæ.

SUBFAMILY 1. DIPYLIDIINÆ Styles 1896.

Tæniidæ, with armed rostellum and unarmed suckers. Genital pores marginal. Genitalia simple or double. Uterus becomes divided into ovarium follicles, or entirely atrophied, and the eggs are set free into the parenchyma. Eggs with thin transparent shells, with or without appendages.

Genera.—(1) *Dipylidium*; (2) *Hymenolepis*.

Dipylidium R. Leuckart 1863.

Dipylidiinæ of medium or small size, with retractile rostellum armed with several rings of alternating hooks, which have a broad basis. Genitalia duplicated, with pores on each side of a proglottis. Eggs with a double shell.

Dipylidium caninum Linnæus 1758.

Synonyms.—*Tænia canina* Leuckart 1758, *Moniliformis* Pallas 1781, *T. cucumerina* Blochmann 1782, *T. elliptica* Batsch 1786, *Dipylidium cucumerinum* Leuckart 1863.

Dipylidium is frequently found in the dog and the cat, which are its proper hosts; in man it is only an accidental and rare parasite, having been first found by Dubois, a pupil of Linnæus in 1751. Melnikow showed that the scolex was to be found in the dog-louse (*Trichodectes canis*) and in that of the cat (*T. subrostratus*), as well as in the dog-flea (*Ctenocephalus canis* Curtis), the cat-flea (*C. felinis* Bouche), and in that of man (*P. irritans*), but how the infection reaches man is not definitely proved. Recently Blanchard has summarized sixty cases in man up to the year 1907, most of which occur among young children.

Morphology.—It measures 15 to 35 to 40 centimetres in length, and the segments are from 1·5 to 3 millimetres in breadth.

The scolex has the typical rostellum, with three to four rings of hooks, diminishing in size from the first circle, where they are 12 to 15 μ, to the last, where they are only 5 to 6 μ in length, and four suckers, which are unarmed.

The genitalia are double, with spores on each side. The eggs are round, from 43 to 50 μ in diameter, with a thin shell.

Life-History.—The ripe proglottides by their own movement pass through the anus, and get into the fur, where the eggs infect the dog and cat louse, or flea, in which they develop into cysticercoids (*Cryptocystis trichodectis* Villot 1882).

The dog bites the louse or flea, and infects itself, and may pass on the cysticercoids to man by licking. The cat licks its fur, and gets infected in that manner.

Blanchard thinks that the cat spreads the parasite by infecting milk with the cysticercoids when it steals a drink from a bowl, the contents of which are afterwards given to children.

Hymenolepis Weinland 1858.

Synonym.—*Diplacanthus* Weinland 1858, *nec* L. Agassiz 1842.

Tæniidæ with small head, with armed, well-developed, or unarmed, rudimentary rostellum. Neck long. Proglottides serrated, longer than broad. Genital pores always on the left. Three testes. Eggs with three shells.

Type.—*H. diminuta.* The genus possesses two subgenera, *Hymenolepis* and *Drepanidotænia.*

Subgenus I. Hymenolepis Sensû Strictû.

With the characters of the genus, but the hooks have the dorsal root much longer than the ventral, and number twenty-four to thirty.

Hymenolepis (Hymenolepis) diminuta Rudolphi 1819.

Synonyms. — *Tænia diminuta* Rudolphi 1819, *T. leptocephala* Creptlin 1825, *T. flavopunctata* Weinland 1858, *T. varesina* Parona 1884, *T. minima* Grassi 1886.

It is a parasite of *Mus norvegicus*, *M. musculus*, and *M. rattus alexandrinus*, being not uncommon in rats in Ceylon.

The first human specimen was discharged by a child aged nineteen months, and was presented to the Boston Medical Improvement Society by Dr. Ezra Palmer in 1842. Since then a number of cases have been recorded in Philadelphia, Sicily, Italy, France, and South America.

Morphology.—The worm measures 20 to 60 centimetres in length, and up to 3·5 millimetres in breadth. The head is very small, only 0·2 to 0·5 millimetre in diameter, club-shaped, and has a rudimentary, unarmed rostellum and four elliptical suckers. The segments measure 0·66 millimetre in length by 3·5 millimetres in breadth. The anterior proglottides show a yellow spot (hence the name *T. flavopunctata*), caused by the distended receptaculum seminis. The posterior proglottides show a brownish-grey colour, due to the mature uterus. The genital pore is situated laterally. The eggs are oval, with a diameter of about 60 μ.

Life-History.—It is a common parasite in rats and mice, while the cysticercus lives in the larva and imago of the meal-moth (*Asopia farinalis*), in an earwig (*Anisolabis annulipes*), and in the beetles *Acis spinosa* and *Scaurus striatus*.

The infection in man is mostly among infants and children.

Hymenolepis (Hymenolepis) nana Von Siebold 1852.

Synonyms.—*Tænia murina* Dujardin 1845, *nec* Gmelin 1790; *T. nana* von Siebold 1852, *nec* van Beneden 1867; *T. ægyptiaca* Bilharz 1852; *Diplacanthus nanus* Weinland 1858.

This is the dwarf tapeworm of man, and was discovered by Bilharz in the ileum of a boy who died of meningitis in Cairo. It is found in Egypt, Europe, North and South America, Siam, and Japan, and is by no means a rare parasite in man. Calandruccio estimates that 10 per cent. of the children in Sicily are affected. Stiles reports 4·8 per cent. for 125 children in Washington. The number found varies from one or two to several thousands in one individual.

There is doubt as to whether this worm is or is not identical with *Hymenolepis nana fraterna* Stiles 1906, which is common in rats and mice. Probably it is distinct from this parasite, because Grassi and Looss were unable to transmit it to mice.

Morphology.—It is the smallest tapeworm in man, measuring only 10 to 15 millimetres in length, and from 0·5 to 0·7 millimetre in breadth.

The head is globular, and provided with a rostellum with one ring of twenty-four to thirty hooks, which are very small, 14 to 18 μ in length. The neck is relatively long.

There are about 150 proglottides, 0·4 to 0·9 millimetre in breadth and 0·014 to 0·030 millimetre in length. The genital pore is marginal. The mature uterus contains about thirty or more eggs, which are oval, and measure 30 to 48 μ, and contain onchospheres measuring 16 to 19 μ in diameter.

Life-History.—It is believed that the cysticercus will be found in some insect.

The nearly related *T. nana fraterna* completes its development entirely in the rat, for the cysticercus develops in the villus, while the adult lies in the lumen of the intestine.

Pathogenesis.—Owing to its small size it is apt to be overlooked, but there is no doubt that it spreads in crowded institutions and poorer families. Apparently, when the parasite occurs in small numbers, no symptoms result, but in considerable numbers disturbance may occur, which has been assigned by Mingazzini to the effects of toxins.

Treatment.—Male-fern is the best treatment (*vide* p. 393).

Prophylaxis.—While it is doubtful whether *T. nana* and *T. nana fraterna* are the same or different species, it will be necessary to guard against the contamination of food by rats and mice. Moreover, it must be remembered that the infection spreads in crowded dwellings, and therefore isolation of the infected child should be insisted upon.

Subgenus 2. Drepanidotænia Railliet 1892.

With the characters of the genus, but the hooks have a dorsal root much larger than the ventral, and are only eight to twenty in number.

Hymenolepis (Drepanidotænia) lanceolata Blochmann 1782.

Synonyms.—*Tænia lanceolata* Blochmann 1782, *T. anserum* Frisch 1727, *T. acutissima* Pallas 1781, *T. anseris* Blochmann 1779, *T. lanceola* Batsch 1786, *Halysis lanceolata* Blochmann 1803.

It is common in ducks, geese, and other birds, including the flamingo, and has been found in man in Europe.

Morphology.—It is about 30 to 130 millimetres in length and 5 to 18 millimetres in breadth, with a very small globular head. Eggs, with three envelopes, oval (50 by 35 μ).

Life-History.—The cysticercoid lives in a cyclops, which is eaten by ducks and geese.

SUBFAMILY 2. DAVAINEINÆ Braun 1900.

Rostellum and suckers armed. Eggs mostly encapsuled.

Genus.—*Davainea.*

Davainea R. Blanchard 1891.

Davaineinæ, with a globular head, armed with two rings of hammer-like hooks and four suckers, surrounded by several rings of hooks.

Species.—*D. madagascariensis ; D. asiatica.*

Davainea madagascariensis Davaine 1869.

Synonym.—*Tænia madagascariensis* Davaine 1869, *T. demarariensis* Daniels 1895.

This worm was first discovered by Grenet in children at Mayotte (Comores).

It has also been observed in Mauritius, Bangkok, Nossi-Bé, and British Guiana.

Morphology.—The worm is 25 to 30 centimetres in length, with a maximum breadth of 1·4 millimetres. The scolex has four large suckers and a rostellum, with ninety hooks (18 μ long). The proglottides number from 500 to 700, being 2 millimetres long by 1·4 millimetres broad. Genital pores are unilateral, and near the proximal corner. Testes number about fifty, with a long vas deferens and a fusiform, cirrus pouch. The receptaculum seminis is long and broad. The uterus is composed of a number of tubes, rolled up on each side into an almost spherical coil. When mature, these windings uncoil and fill the proglottides; then they lose their walls, and the eggs, lying free in the parenchyma, become surrounded by proliferating cells, which form capsules for them.

As many as 300 to 400 of these capsules may exist in one proglottis, arranged in transverse rows.

The egg consists of the usual two membranes and an onchosphere, which is 8 by 15 μ.

Life-History.—The life-history is unknown, but it is suggested that the cysticercus may be found in the cockroach (*Periplaneta orientalis* or *P americana*).

Allied genera are common in rats, hares, fowls, pigeons, turkeys, pheasants, partridges, grouse, and other birds.

Davainea asiatica von Linstow 1901.

Synonym.—*Tænia asiatica* von Linstow 1901.

This worm was found in a person in Aschabad, near the northern frontier of Persia, and consists of 750 proglottides without a head. The genital pores all lie on the same lateral border. The testes are globular, the cirrus pouch pyriform. The female organs lie anteriorly, with a large ovary and a small vitellogene gland. There is a large receptaculum seminis. The uterus breaks into sixty to seventy large egg follicles. Nothing is known about the appearance of the mature egg, or about the life-history.

SUBFAMILY 3. TÆNIINÆ Stiles 1896.

Tæniidæ, usually of considerable length, with segments longer than they are broad. Scolex with either a rostellum armed or unarmed, or an apical sucker. Genital pores irregularly arranged on the lateral borders. Genitalia single. Testes numerous, placed laterally. Ovary shell and vitellogene gland situated posteriorly. Uterus, a single median trunk, from which lateral branches develop later. Eggshell thin; embryonic envelope (embryophore) thick, with radial stripes. Cysticercus generally in herbivora, adults in carnivora.

Tænia Linnæus 1758.

Tæniinæ with the characters of the subfamily. The genus *Tænia* is subdivided into three subgenera:

Subgenus 1. *Tænia* Linnæus 1758. Type: *Tænia solium.*

Subgenus 2. *Tæniarhynchus* Weinland 1858. Type: *T.* (*Tæniarhynchus*) *saginata.*

Subgenus 3. *Multiceps* Goeze 1782. Type: *T.* (*Multiceps*) *cœnurus.*

Tænia (Tænia) solium L. 1758.

Synonyms.—*T. cucurbitina* Pallas 1766, *T. pellucida* Goeze 1782, *T. vulgaris* Werner 1782, *T. dentata* Batsch 1786, *Halysis solium* Zeder 1803, *T. armata humana* Brera 1808.

The name 'solium' is derived from a Syrian term *schuschl*, meaning a chain, which has arrived at its present form by being first turned into Arabic and finally into Latin. It is often called the armed tapeworm.

This worm is cosmopolitan in its distribution, for it can be found wherever a pig and a man can live, for the cysticercus lives in the pig, man, and rarely in sheep and dogs, while the tapeworm only lives in man. Even monkeys appear not to be capable of infection.

It seems to be more widespread in the Tropics than in the Temperate Zone. It is not uncommon in Ceylon, and it is apparently common in Panama.

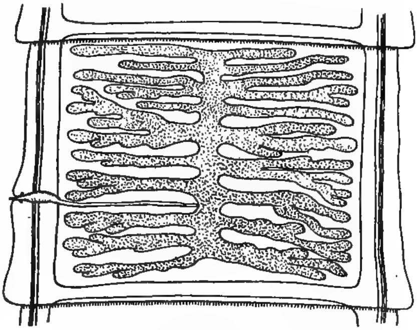

FIG. 151.—PROGLOTTIS OF TÆNIA SOLIUM L. (After Stiles.)

Morphology.—Length usually 2 to 3 metres, but may reach 8 metres. Mature segments measure 5 to 6 millimetres in breadth. Scolex provided with a rostellum, which may be pigmented and is armed with a double row of alternately large and small hooks, which number from twenty-two to thirty-two, and with four hemispherical suckers. The neck is long. Proglottides number from 800 to 900, with a length of 10 to 12 millimetres in mature segments. Genital pore lateral and irregularly alternate. The mature uterus has seven to ten ramified lateral branches, and contains three ovaries, the third being formed by subdivision of the one on the side of the genital pore. Eggs globular, pale yellow in colour, from 31 to 38 μ in diameter.

Life-History.—The adult worm lives solely in the human intestines, from which the onchosphere with their envelopes escape in the fæces, and are apt to be eaten by pigs, or these may be infected by contaminated food or water. The cysticercus, often called *Cysticercus cellulosæ* (synonym, *C. acanthotrias*), develop in the flesh of the pig. If this flesh is eaten in an undercooked condition, the cysticercus infects the human being and forms the tapeworm. Occasionally man becomes infected with *Cysticercus cellulosæ*, most commonly in the brain, then the eye, the muscles, liver, lungs, etc., where they are sometimes few, sometimes numerous. This infection must be due to contaminated food or water.

The tapeworm can live for years in the intestine of man. A variety called *T. solium, var. abietina* Weinland, originally found in a Chippewa Indian, belongs probably to this species.

Pathogenesis.—The intestinal symptoms are not severe, but colicky pains and diarrhœa alternate with constipation. The patient may slowly emaciate. The danger of this infection is the entry of eggs into the human being and the formation of cysticerci in the organs.

Treatment.—Warn the person affected to be very careful to keep his hands clean, and to avoid infecting himself and other people with eggs. Kill the tapeworm with extract of male-fern given in capsules (four to eight of 10 minims each), or in emulsion on an empty stomach, and followed after four to six hours by a saline purgative.

Prophylaxis.—Fæces should be so treated as not to infect pigs, and the flesh of these animals should be carefully cooked.

Tænia (Tæniorhynchus) saginata Goeze 1782.

Synonyms.—*T. solium* Linnæus 1767 p.p., *T. cucurbitina* Pallas 1781 p.p., *T. mermis* Brera 1802, *T. dentata* Nicolai 1830, *T. lata* Pruner 1847, *Bothriocephalus tropicus* Schmidtmüller 1847, *T. mediocanellata* Küchenmeister 1855, *T. zittavensis* Küchenmeister 1855, *T. tropica* Moquin-Tandon 1860.

This is the unarmed beef-worm or the fat tapeworm, which has a cosmopolitan distribution, the adult being known only in man and the cysticercus in cattle, though it can be produced experimentally in a number of animals. It is very common in the tropics, especially in Africa and Asia.

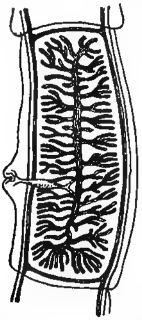

FIG. 152.—PROGLOTTIS OF TÆNIA SAGINATA GOEZE. (After Stiles.)

Morphology.—It measures 4 to 8 to 10 metres in length, and has been said to attain much greater length. A mature segment is 4·7 millimetres in breadth. The head possesses four hemispherical, often pigmented, suckers, and a sucker in place of a rostellum. The neck is long. The proglottides number about 1,000 segments, with a length of about 16 to 20 millimetres when mature. The genital pores are arranged irregularly at the sides, and the median uterus produces twenty to thirty-five ramified lateral branches. Malformations of the segments are not uncommon. Eggs globular, often with the original shell, to which may be attached one to two filaments and the two embryonic envelopes, as well as the onchosphere. The inner embryonic envelope is oval, striated, measures 30 to 40 μ in length by 20 to 30 μ in breadth. Segments can escape *per anum* by their own action.

Life-History.—The adult worm lives in man, and the embryophore, escaping in the fæces, enters cattle by means of contaminated food or water, and develops in their muscles into the *Cysticercus bovis*, which is rather small—only 7·5 to 9 millimetres in length and 5·5 millimetres in breadth. The tongue and the muscles of mastication, especially the pterygoids, are chiefly affected.

Man becomes infected by eating under-cooked meat. It can live in him for a number of years. The cysticercus very rarely occurs in man.

Pathogenesis.—It is believed to be more difficult to kill medicinally than *T. solium* and to produce more severe anæmia.

Treatment.—As for *T. solium*.

Prophylaxis.—Prevent human fæces contaminating the food of cattle, and have the meat, especially the tongue and the pterygoid muscle, inspected in the slaughter-house.

Tænia (Tæniorhynchus) africana von Linstow 1900.

Two specimens of this worm were found in a negro in German East Africa, at Langenburg, near Lake Nyassa.

Morphology.—It is about 1·4 metres in length. The scolex is provided with an apical sucker in place of a rostellum, and also with four ordinary suckers. The neck is very short. The proglottides vary in length and breadth, according to position, but are always broader than they are long.

The ripe segments are 9 millimetres broad by 1·20 millimetres thick. Their number is about 600. The genital pore is irregularly alternate on the lateral border. The testes are very numerous, and the vas deferens much convoluted, with a thick, pear-shaped cirrus pouch. The cirrus is beset with bristles, as is the vagina. The receptaculum seminis is large. The ovary is large and double, and the vitellogene gland is situated at the posterior border. The mature uterus consists of a median portion with fifteen to twenty-four non-ramified lateral branches.

The embryophore is thick, with radial markings, round or oval (39 by 33 μ).

Life-History.—The life-history is not known, but it is suggested that the cysticercus may live in *Bos indicus*, the hump-backed cow, the flesh of which the natives of East Africa eat raw.

Tænia (Tæniorhynchus) hominis von Linstow 1902.

This worm was found by Anger in a man in Aschabad in Siberia.

The length was 70 millimetres. The scolex had a rudimentary rostellum without hooks. There were four unpigmented suckers, behind which there was a ring-shaped swelling. Nothing further is known about this parasite.

Tænia (Tæniorhynchus) philippina Garrison 1907.

This specimen was found by Hare in a prisoner in Bilibid prison, in the Philippine Islands, in 1905.

Morphology.—The length is 80 to 100 centimetres; maximum breadth, 1 centimetre. Head cuboid, with an unarmed retractile rostellum and four suckers. Neck segmented. Proglottides number about 800, being sexually mature about the 470th. Mature proglottides 4 to 5 millimetres in width and 0·8 to 1 millimetre in length. Surfaces and margins extend posteriorly in an elongated cuff-like projection over the succeeding segment. Testes 130 to 160 μ in length, and from 60 to 80 μ in breadth. Vas deferens without vesicula seminalis; cirrus and pouch present. Genital pore situated irregularly on the lateral borders. Ovaries, with two unequal transversely elongated lobes, close against the vitellogene gland. Vagina without setæ and with two coils. Uterus stem with a **V**-shaped course posteriorly, and with four to six distinct coils anteriorly. Mature uterus very compact, with a median stem and numerous long, slender dichotomous branches.

Embryophore oval, 35 to 41 μ long, and 26 to 35 μ broad.

Life Cycle.—Life-history not known.

Tænia confusa Ward 1896.

This worm has so far only been found in Lincoln, Nebraska, U.S.A.

Morphology.—Length about 8½ metres, breadth 5 millimetres, scolex unknown. Segments much longer than they are broad, 27 to 35 millimetres long by 3·5 to 5 millimetres broad. Genital pore irregularly placed behind the middle of the lateral border. Testes numerous, vas deferens not much coiled, cirrus pouch thick-walled. Cirrus beset with little hairs. Receptaculum seminis globular; ovary small and double, bean-shaped. Vitellogene gland narrow and triangular; shell gland globular. Uterus, when mature, consists of a median trunk, and fourteen to eighteen short dichotomous branches on each side. Embryophores are oval, thick, and striated (39 by 30 μ).

Life Cycle.—Nothing is known.

Tænia bremneri Stephens 1907.

This worm was found by Dr. Bremner in a Fullani woman in Northern Nigeria.

Morphology.—The head is not known. The segments examined measured, on an average, 28·6 by 8·5 millimetres, but ranged from 21 by 6 millimetres to 32 by 29 millimetres in size. The central uterine axis has twenty-two to twenty-four ramified lateral branches, and one terminal branch with four to five ramifications. The genital pore is prominent, and lies behind the middle of the segment. Eggs measure on an average 38 by 30·4 μ.

Life Cycle.—Nothing is known at present about the life-history.

Echinococcus Rudolphi 1802.

Synonym.—*Acephalocystis* Laennec 1804.

Species.—*Echinococcus granulosus* Batsch 1786, *E. multilocularis* Huber 1896.

Echinococcus granulosus Batsch 1786.

Synonyms.—*Tænia echinococcus* Zeder 1803, Siebold 1853; *T. nana* van Beneden 1861, *nec* Siebold 1853; *Echinococcifer echinococcus* Weinland 1861.

Hydatid disease appears to have been known since the days of Hippocrates. In 1684 Redi suggested that the cysts were animal in origin, and in 1760-67 Pallas clearly showed their relationship to tapeworms (*Tænia hydatigena*).

It appears doubtful whether there are two species of worms associated with hydatid disease, but the appearance of the larvæ and the geographical distribution tend to separate the genus into two species.

Echinococcus granulosus causes the cystic form of hydatid disease, which is found most markedly in Iceland and Australia, but also exists all over Europe, and is known in New Zealand. It is rare in India, and the only case we have seen in Ceylon came from South Africa, where it occurs; but Begbie has recently described another case in Ceylon. It is known in the Philippine Islands, and is not uncommon in Egypt and Algeria. The mature worm, which is very small, lives in the small bowel of the dog, the jackal, and the wolf in large numbers, while the cysticercus is found in man, sheep, ox, and pig.

Morphology.—It is very small, only 2·5 to 5 to 6 millimetres in length, and is composed only of a scolex and three to four segments. The scolex has four suckers and a rostellum armed with a double row of twenty-eight to fifty hooks, which vary in size, the larger being 40 to 45 μ in length, and the smaller 30 to 38 μ in length. The genital pores alternate.

The testes are numerous, the vas deferens spirally coiled, the vitellogene gland double, the shell gland round. The mature uterus has only lateral protuberances, no true branches, and the eggs may form heaps.

The egg is globular, 30 to 36 μ in diameter.

Life Cycle.—The dog infects man with the onchospheres, usually directly when being petted. Infection may, however, be brought about by contaminated food.

On arrival in the stomach, the onchosphere escapes from its embryophore and bores its way into the liver or some other organ. Here it grows, and forms a cyst with a thick outer cuticle, inside which is fluid enclosed by a layer of parenchyma, the endocyst, composed of two layers of cells. The irritation caused by the growth of this cyst produces a connective-tissue coat, formed by the organ in which the cyst is growing. The cyst in this condition is called an acephalocyst (*Echinococcus cysticus sterilis*), and is often found in cattle.

The next stage is the formation of the brood capsule. The inner layer of the endocyst grows inwards, forming large numbers of small hollow capsules (brood capsules), which have the endocyst externally and the cuticle internally. On these capsules heads develop. The cyst now forms the *Echinococcus cysticus fertilis*, found in domestic animals.

In man, however, daughter-cysts appear between the strata of the cuticle, into which cells belonging to the endocyst have found their way and formed cysts, with an external cuticular and an internal parenchymal layer. These cysts may, of course, bulge, and escape externally or internally. If externally, they then lie between the capsule and the mother-cyst and form *Echinococcus hydatidosus exogenus*, or if internally, they fall into the interior of the mother-cyst and form *Echinococcus hydatidosus endogenus*. These daughter-cysts may remain sterile or produce brood capsules and heads. Grand-daughter-cysts may be formed in the same way. The wall of the mother-cyst may disappear, leaving the daughter-cysts free.

Of all these varieties, the endogenous cyst is the most common. It may reach several pounds in weight, with hundreds of daughter-cysts.

It is believed that the usual cycle of life-history takes place in the dog and the sheep. Manson suspects the jackal in India as a spreader of the disease to man. Stirling and Verco lay down the following factors as necessary for the spread of the disease :

1. Sufficiency of infected dogs.
2. Domestic herbivora, especially sheep, as intermediary hosts.
3. Conditions favourable for the transmission of the parasite from the dog to man.
4. Facility of access of dogs to infected carcasses.

Perhaps, however, the eggs gain access to the human body through contaminated food and dust.

Pathogenesis.—The cysts grow but slowly, consequently organs adapt themselves to the pressure, so that symptoms may be wanting and depend entirely upon whether the organ can or cannot expand.

If, however, fluid escapes from a cyst, urticarial eruptions, or even rigors, with local pain and tenderness, may result.

Prophylaxis.—Prophylaxis must be on the lines indicated by the factors above mentioned—viz., registration of dogs, destruction of pariah dogs, non-feeding of dogs with raw meat, clean kennels, non-handling of dogs.

Echinococcus multilocularis Leuckart 1863.

Synonym.—*Echinococcus osteoklaster* Huber 1896.

This is the parasite which causes the alveolar or multilocular form of hydatid disease, which is very different from the ordinary form. The disease was first observed by Ruysch in 1721, and was generally looked upon as a colloid cancer, until Virchow in 1856 showed that it had its origin in a worm. Mangold and Müller consider that by feeding experiments they obtained from it a *Tænia* different from *E. granulosus* in the hooks and the distribution of the ova.

Melnikow-Raswedenkow gives quite a different life-history for this parasite, which, if correct, will make it a new species. Further, there is the support of Stiles, Stirling, Verco, and others for the differentiation of the parasites from one another.

This form of hydatids occurs in man, sheep, and pigs, but principally in large cattle.

The geographical distribution is interesting, it being mostly found in South Germany, Switzerland, the Austrian Alpine region, Russia, and East Siberia, in which districts it occurs in large cattle and man, whereas it is absent from Iceland and Australia and European districts where sheep are common and where the other form is frequently met with.

Morphology.—Melnikow-Raswedenkow says that the cysts are composed of parenchyma internally and externally, the latter being in direct contact with the tissue of the host, and producing, it is said, not merely scolices, but immature amœboid embryos, which spread the cyst by continuity, or may enter the blood-stream and form metastases.

An amœboid embryo develops into a much-folded chitinous vesicle, having parenchyma both internally and externally. This parenchyma produces poisons which act upon the host. The cyst is looked upon as the homologue of a ripe proglottis, because it can produce living embryos, for the parenchyma can form scolices, immature embryos without a capsule, and mature ovoid embryos enclosed in a chitinous capsule.

The scolices, however, are frequently destroyed by phagocytosis, because they are situated in direct contact with the host's tissues. Hence the failure of feeding experiments, as the scolices arrive in the intestine damaged.

The result of this development is to produce a collection of cysts, measuring from 0·1 to 5 millimetres in diameter, embedded in connective tissue. Disintegration may begin in the centre of the masses of the cysts. Whether the *Tæniæ* obtained by feeding experiments are the same as *T. echinococcus* or not is uncertain.

Pathogenesis.—It produces a primary tumour in the liver, brain, spleen, kidney, or adrenals, with metastases in different parts of the body. The symptoms produced vary with the region affected, but eventually, perhaps after years, lead to anæmia, emaciation, and weakness, which cause death.

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CHAPTER XVI

BIOLOGICAL CAUSES OF DISEASE (*continued*) —NEMATHELMINTHES

Nemathelminthes — Nematoda — Anguillulidæ — Angiostomidæ — Gnathostomidæ — Filariidæ — Mermithidæ — Trichinellidæ — Strongylidæ— Ascaridæ — Gordiacea — Acanthocephala — References.

PHYLUM II. NEMATHELMINTHES

METAZOA, worm-like in form, tubular, or filiform, unsegmented, but covered with a cuticle which may be ringed. Without appendages or limbs, but usually with bristles, hooks, papillæ, or, rarely, suckers. Usually with an alimentary canal, but without any closed vascular system, and without respiratory organs. With an almost complete absence of cilia. Sexes are separate. Usually parasitic through some part of the life cycle, in which the larvæ develop in a different host or organ from that occupied by the adult. The larvæ may be free and the adult parasitic, or *vice versâ*.

The Nemathelminthes are extremely important to the student of tropical medicine, for they include some of the most potent agents of disease—*e.g.*, *Agchylostoma duodenale* and the *Filariidæ*. Recent researches have shown that, no matter how common the worm may appear to be, it is advisable to carefully study it, as it has been found that several species and genera have been included in an old species which was thought to be so well known that nothing new could be discovered concerning it—*e.g.*, *Ascaris lumbricoides*, in examining specimens of which Leiper has separated two new genera.

The Nemathelminthes can be divided into two classes:

CLASS I.—Anterior end not provided with an armed proboscis; intestine present either complete or in part rudimentary.

This class includes two orders:

Order 1. Nematoda.
Order 2. Gordiacea.

CLASS II.—Anterior end provided with an armed proboscis; intestine absent.

Order 3. Acanthocephala.

CLASS I.

ORDER I. NEMATODA.

Nemathelminthes with white filiform bodies, with usually a complete alimentary canal in the adults, but sometimes this may be represented by only an œsophagus and a rudimentary intestine; with papillæ on the head. The male with one testis, a strongly recurved posterior extremity, and usually spicules. The female with a vulva distinct from the anus, except in the Cloacinæ.

The Nematoda are parasitic, as a rule, but minute forms can be met with in moist soil all over the world. The body is enclosed in a thick, transparent, smooth, or ringed cuticle, which may form hooks, spines, or lateral fins.

Under the cuticle comes a syncytium called the epidermis, under which is the peculiar muscular layer cut into four quadrants by thickenings of the epidermis, which project inwards, surrounding dorsally and ventrally a nerve cord, and laterally an excretory canal. Under the skin comes the large undivided body cavity, which is not of the nature of a true cœlom, as it is not between the two layers of the mesoblast, but between mesoblast externally and hypoblast internally, and contains a fluid which may represent the hæmolymph fluids of higher animals.

The digestive system consists of a mouth situated at the anterior end, and surrounded by two to six lips, which opens into a thick muscular suctorial œsophagus lined with chitin, the posterior part of which may be swollen into a bulb and armed with teeth.

The œsophagus opens into the intestine, which is a flattened tube leading to the short rectum, which ends in the anus.

The excretory system consists of two tubes lying in the lateral line, and uniting anteriorly to open in a pore situated in the mid-ventral line just behind the mouth.

The nervous system consists of a circumœsophageal ring, with six anterior and six posterior nerve trunks.

The sexes are separate. The male reproductive organs consist of one tube divisible into testes, vas deferens, vesicula seminalis, and ductus ejaculatorius, which opens on the ventral surface of the rectum close to the anus, while the posterior end of the body is modified for sexual purpose with spines and papillæ. The female reproductive organs consist of two much-coiled tubes divisible into ovary, oviduct, and uterus, which join together to form the simple vagina, which opens about the middle of the body in the mid-ventral line, or just in front of the anus.

Biology.—They appear to live upon the juices of the part of the body in which they are found. Generally this is the intestine, the contents of which supply them with ample food. But some of them are capable of entering the villi of the intestine.

Life-History.—Sometimes the life-history is fairly simple, or is supposed to be so, for it is possible that we are not well acquainted with details.

Other life-histories are most complicated, and must be dealt with in detail.

Pathogenesis.—Some of the worms are markedly pathogenic, while others usually produce but slight effects.

Classification.—The Nematoda are classified into the families: (1) Enoplidæ, (2) Anguillulidæ, (3) Angiostomidæ, (4) Gnathostomidæ, (5) Filariidæ, (6) Mermithidæ, (7) Trichinellidæ, (8) Strongylidæ, (9) Ascaridæ.

The Enoplidæ are free-living, and do not concern us.

The following table gives the parasites known in man, excluding a number of doubtful Filariidæ:

Family.	Genus and Subgenus.	Species.
Anguillulidæ	Anguillula	A. aceti.
	Anguillulina	A. putrefaciens.
	Rhabditis	R. niellyi.
	Leptodera	L. pellio.
Angiostomidæ	Strongyloides	S. intestinalis.
Gnathostomidæ	Gnathostoma	G. siamese.
Filariidæ	Filaria	F. bancrofti.
		F. perstans.
		F. demarquai.
		F. magalhæsi.
		F. medinensis.
		F. volvulus.
		F. conjunctivus.
		F. taniguchi.
		F. labialis.
	Loa	F. loa.
	Hamularia	F. equi.
	Microfilaria	F. powelli.
		F. philippinensis.
	Agamofilaria	F. oculi.
		F. georgiana.
Trichinellidæ	Trichinella	T. spiralis.
	Trichuris	T. trichiura.
Strongylidæ	Dioctophyme	D. renale.
	Strongylus	S. gibsoni.
	Metastrongylus	M. apri.
	Trichostrongylus	T. instabilis.
		T. probolurus.
		T. vitrinus.
	Agchylostoma	A. duodenale.
	Necator	N. americana.
	Triodontophorus	T. deminutus.
	Œsophagostomum	O. brumpti.
	Physaloptera	P. caucasica.
		P. mordens.
Ascaridæ	Ascaris	A. lumbricoides.
		A. maritima.
		A. texana.
	Toxascaris	T. canis.
	Belascaris	B. mystax.
	Oxyuris	O. vermicularis.

FAMILY 2. ANGUILLULIDÆ.

Very small Nematoda, mostly free-living, rarely parasitic, with an oral cavity armed with a tooth or spine, and an œsophagus with a double dilatation. Male with two spicules, and sometimes a bursa copulatrix. Female with a pointed tail, and a vulva situated in the middle of the body.

Genera.—(1) *Anguillula*, (2) *Anguillulina*, (3) *Rhabditis*, (4) *Leptodera.*

Anguillula Ehrenberg 1826.

Anguillulidæ with small mouth, œsophagus with two dilatations, of which the posterior has valves. Male without bursa, spicules with accessory pieces feather-shaped. Female with the vulva in the hinder portion of the body; uterus asymmetrical.

Anguillula aceti Müller 1783.

Anguillula aceti is the common vinegar eel, which has several times been reported as occurring in the human bladder, but the method of infection is unknown.

Morphology.—Cuticle not striated, body cylindrical, tapering a little to the anterior, but considerably to the posterior end. Male 1 to 2 millimetres long and 24 to 40 μ broad, with two pre-anal and one post-anal papillæ. Two equal spicules 38 μ long. Female, 2·4 millimetres long and 40 to 72 μ broad. Vulva near the equator. Embryos 222 by 12 μ.

Pathogenesis.—Nil.

Anguillulina Gervais and Beneden 1859.

Synonym.—*Tylenchus* Bastian 1864.

Anguillulidæ possessing a spine on the oral cavity. Male bursa without papilla; uterus asymmetrical.

Species.—*Anguillulina putrefaciens.*

Anguillulina putrefaciens Kühn 1879.

Synonyms.—*Tylenchus putrefaciens* Kühn 1879, *Trichina contorta* Botkin 1883.

This small nematode lives in onions, and it or other varieties may at times find access to the stomach with the food, and be rejected by vomiting, as reported by Botkin in 1883.

Rhabditis Dujardin 1845.

Small Anguillulidæ with no teeth in the oral cavity, with accessory pieces to the two male spicules, and without lateral ridges.

Rhabditis niellyi Blanchard 1885.

Synonym.—*Leptodera niellyi* Blanchard 1885.

This parasite was described by Nielly in 1882 in a boy who suffered from an itching papular eruption in Brest, which he had never left.

The parasites were found in the papules, and also in the blood at the beginning of the illness, but not in the fæces, urine, or sputum.

The parasites measured 0·33 by 0·03 millimetre in width, and possessed a cuticle with delicate transverse striation, a double-bulbed œsophagus, and an intestine, but no genital organs.

It was thought that he might have got infected by water, and that the embryos entered the blood via the intestine, and so passed to the skin; but in the light of our knowledge of the life-history of *Agchylostoma duodenale*, it might possibly be that the larvæ were entering by the skin, and passing into the blood to reach the bowel. It is obvious that the parasite is immature, and that its characters are hardly of specific value.

Possibly it was some such rhabdite that O'Neil saw in craw-craw papules on the West Coast of Africa, or his parasite may have been a blood *Microfilaria*.

Leptodera Dujardin.

Anguillulidæ with mouth, guarded by two, three, or six lips. Male with or without bursa, which, when present, never surrounds the point of the tail. Two equal spicules, and three pre-anal papillæ.

Female with the tail prolonged into a long unsymmetrical point.

Leptodera pellio Schneider 1866.

Synonyms.—*Pelodera pellio* Schneider 1866, *Rhabditis genitalis* Scheiber 1880.

Leptodera pellio is merely an occasional parasite in man. Infection arises in rather a peculiar manner. The larva lives in the earthworm (*Lumbricus terrestris*), while the adults exist in decomposing matter in the soil.

The Hungarian peasants use soil for making poultices, from which the little worms apparently make their way into the vaginæ of women and live there. Oerley has shown experimentally that they will live in the vagina of a mouse.

Morphology.—Male, 0·8 to 1·05 millimetre in length, with a bursa supported by seven to ten ribs on each side. Spicules, which are not quite alike, measuring 27 to 33 μ in length. Female, 0·9 to 1·3 millimetres in length, with a vulva slightly posterior to the middle of the body.

Pathogenesis.—Nil.

FAMILY 3. ANGIOSTOMIDÆ.

Nematoda characterized by heterogony, each species having a free bisexual rhabdite form and a parasitic hermaphrodite filarial form.

Strongyloides Grassi 1879.

Synonyms.—*Pseudorhabditis* Perroncito 1881, *Rhabdonema* Leuckart 1882.

The parasitic form has an unarmed mouth, long cylindrical œsophagus, which reaches nearly to the middle of the body. The non-parasitic form has a small mouth, short œsophagus with a double dilatation, in the hinder part of which are small teeth. The male spicules are of equal size.

Strongyloides intestinalis Bavay 1876.

Synonyms.—*Anguillula intestinalis et stercoralis* Bavay 1877, *Leptodera intestinalis et stercoralis* Cobbold, *Pseudorhabditis stercoralis* Perroncito 1881, *Rhabdonema strongyloides* Leuckart 1883, *R. intestinale* Blanchard 1886.

History.—This little worm, which is not uncommonly met with in fæces, was first described in 1876 by Normand in the fæces and the intestine of French soldiers just returned to Toulon from Cochin China.

At first it was thought that there were two species—one in the fæces (*Anguillula stercoralis*), and the other in the bowel (*A. intestinalis*)—but Leuckart showed that they were but succeeding generations of one life cycle. It is found in Europe, Africa, India, Ceylon, Indo-China, China, the Philippines, Oceania, the United States, the West Indies, and Brazil.

The fully developed worm is found in the duodenum and jejunum, into the mucosa of which it has bored its way deeply.

Morphology.—The parasitic adult worm is very small—2·2 millimetres long and 34 μ broad—with a finely striated cuticle, and a mouth surrounded by four lips, leading into a cylindrical œsophagus, equal in length to one-quarter of the whole body. The anus is just in front of the tip of the tail. Inside this parasite can be seen ellipsoidal eggs. The sex of this parasite is doubtful. Is it a hermaphrodite, in which the male organs, after serving their purpose, have degenerated, or is it a parthenogenetic female? At present these questions cannot be answered definitely. Most probably it is a hermaphrodite. The eggs measure 50 to 58 μ in length by 30 to 34 μ in breadth, and are arranged in strings surrounded by a delicate tubular structure. They occur in the fæces only during attacks of diarrhœa.

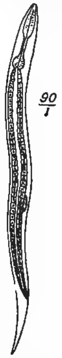

FIG. 153.—RHABDITIFORM EMBRYO OF STRONGYLOIDES INTESTINALIS BAVAY AS FOUND IN HUMAN FÆCES.

(After Looss.)

Life-History.—The eggs are oviposited into the mucosa of the host's intestine, and the embryos hatch and find their way into the lumen, and are evacuated with the fæces. On reaching water, these embryos grow into adult male and female forms, which conjugate, and then the female lays eggs. The eggs produce free-living rhabditiform embryos, which moult and turn into filariform embryos, which have been shown by Mozocchi and van Durne to penetrate the skin, not through the hair-follicles, but through the horny layer into the rete Malpighii, and so into the corium. Their further route has not been worked out. On arrival in the intestine they burrow into Lieberkühn's follicles, and begin to lay their eggs.

Pathogenesis.—The parasite is generally believed to cause a catarrh of the small intestine, though many believe it to be non-pathogenic.

FAMILY 4. GNATHOSTOMIDÆ.

Nematoda, with the whole or only the anterior part of the body covered with minute ramified spines. They live in the stomachs of vertebrates, especially mammals.

One genus: *Gnathostoma* Owen 1836.

Gnathostoma Owen 1836.

Synonym.—*Cheiranthus* Diesing 1839.

With the characters of the family.

Gnathostoma siamense Levins 1889.

Synonym.—*Cheiranthus siamensis* Levins 1889.

Only one specimen is known, which was obtained by Deuntzer from a young Siamese woman in whose breast a hard painful swelling had formed, accompanied with slight fever. Nodules the size of beans appeared in the skin, from one of which a worm was extracted. Two other similar cases have recently been reported.

Morphology.—The specimen is that of a female worm, 9 millimetres long by 1 millimetre broad, with eight rows of bristles around the head, and spines covering the anterior third of the body. Each spine ramifies into three points, of which the middle is the longest. The anterior end was narrow, and the mouth appeared to be bordered by two lips. The posterior end had a three-lobed prominence, at the base of which the anus opened.

Habitat.—Allied species live in the stomach of cats, dogs, pigs, and oxen. One is said to occur in the pariah dogs of Calcutta, and another in the large intestine of monkeys in French Guiana.

FAMILY 5. FILARIIDÆ BRAUN 1895.

Synonyms.—*Filaridea* Carus 1863, *Filariadea* Leuckart 1876, *Filaridæ* Cobbold, *Filarides* Assenova 1899.

Long filiform nematodes with uniform diameter, and a straight head provided with two latero-median and four submedian papillæ. Mouth terminal, with two lips, and occasionally a more or less distinct buccal capsule. Œsophagus slender, elongated, and may be divided into two portions, but has no posterior bulb. Mid-gut present, rectum present, anus subterminal.

Males with one or two unequal spicules and a spirally recurved tail, provided with papillæ, and in some cases with lateral alæ. Females larger than the males, with or without a vulva in the gravid worms, which, when present, is situate anteriorly. Uterus usually double.

All species parasitic and ovoviviparous, with a change of host in at least certain species.

Type Genus.—*Filaria.*

The genus *Filaria* was created by Müller in 1787, unfortunately without naming a particular type, which Stiles suggests should be *Filaria martis* Gmelin 1790 (*F. perforans*). This is found in *Mustela martes* L., the pine-marten of Europe, and was one of the parasites originally described by Müller. This parasite requires to be restudied before definite characters can be given for the genus.

Filaria Müller 1787.

Definition doubtful. Long slender filiform bodies, anterior extremity attenuated, obtuse; posterior very attenuated, more so than the head. Cuticle with or without transverse striation, with or without bosses.

Type.—*F. martis* Gmelin 1790.

With regard to the transverse striation of the cuticle, Stiles remarks that those with marked transverse striation may require to be separated from those which are without; but as the species are little studied on this point, and especially as the type is not well known, the matter will have to stand over for future investigations. It is evident that the whole genus requires careful restudy *in toto*.

Stiles classifies the parasites ascribed to the genus *Filaria* which have been described in man into the following groups: (1) Subgenus *Hamularia* Treutzler 1793; (2) subgenus *Loa* Stiles 1905; (3) subgenus *Filaria* Müller 1783; (4) uncertain; (5) *Microfilaria* (a collective group); (6) *Agamofilaria* (a collective group); (7) *Filocapsularis*; (8) species to be eliminated from *Filaria* and the Filariidæ; (9) species eliminated from *Filaria* and probably from the Filariidæ; (10) species eliminated altogether.

To take the last group first, it appears that the following can probably be eliminated:

1. *Filaria* (?) *hominis oris* Leidy 1850.—This probably belongs to the Mermithidæ, and may have been a mermis accidentally taken into the child's mouth while eating, say, an apple, because it had an obtuse posterior extremity with a recurved hook.

2. *Filaria* (?) *gigas* Prout 1902.—Two embryonic *filarial* structures 220 to 340 μ by 8 to 12 μ, found with rounded head and tapering tail ending bluntly no sheath; stained readily with fuchsin.

Looss thinks that they may be cast skins, and Low thinks that these might be contaminations—*i.e.*, insect hairs; and as Stiles has also adopted this view, the parasite may perhaps be eliminated.

3. *Nematoideum tracheale* Cobbold 1864.

The following can certainly be eliminated:

4. *Filaria* (?) *restiformis* Leidy 1880, as this is *Agamomeris restiformis*, and belongs to the Mermithidæ.

5. *Filaria* (?) *cystica is Oxyuris vermicularis.*

6. *Filaria* (?) *niellyi is Rhabditis niellyi.*

7. *Filaria* (?) *zebra* Mon Grand 1852 is said to be a fibrinous clot, and therefore a species *fictitia*.

The following may have to be eliminated:

8. *Filaria* (?) *kilimaræ* Kolb 1898.—These consist of several female specimens once found free in the abdominal cavity of a fallen Kitu warrior. Oral papillæ are said to have been like *Dracunculus medinensis*.

They were 10 to 20 centimetres in length, and 0·5 to 1 millimetre in diameter white, and resembled *Gordius aquaticus* in general appearance.

With these Kolb classified free-living worms, and therefore doubts are held as to the exact zoological determinations of the species recorded.

9. *Filaria* (?) *romanorum orientalis* Sarcani 1888.—Observed in the blood of a Roumanian woman; 1 millimetre long by 0·3 millimetre broad, with intestine and generative apparatus developed; believed by some to be an adult threadworm

The uncertain species are:

1. *Filaria Species* (?) Cholodkowsky 1896.—Found in whitlow-like tumours on the fingers of peasants in the Twer Government.

2. *Filaria Species* (?) Prout 1902.

Filocapsularis Des Longchamps 1824.

There was a parasite called *Spiroptera hominis* Rudolphi 1819, which appears to have been spurious, being really *Filaria communis*, of which *Filaria piscium* is a synonym.

The only genera left are, therefore: (1) Subgenus *Filaria;* (2) subgenus *Loa;* (3) subgenus *Hamularia;* (4) collective group *Microfilaria;* (5) collective group *Agamofilaria.*

Subgenus Filaria Müller 1787.

Synonyms.—*Fileraria* Rudolphi 1809, *Filaire* Lee 1840, and some misprints.

Definition (Provisional).—Long filiform worms, with unstriated cuticle, without bosses. Mouth small, round, unarmed, terminal, without lips.

Male shorter than the female, with a spirally bent tail provided with lateral cuticular alæ, pre- and post-anal papillæ, and unequal spicules.

Female longer than the male, with vulva anterior, very close to the mouth.

Type.—*Filaria martis* Gmelin 1790 (requires restudy).

Species.—*F. bancrofti* Cobbold 1877, *F. perstans* Manson 1891, *F. demarquayi* Manson 1897, *F. magalhæsi* Blanchard 1895, *F. medinensis* Linnæus 1758, *F. volvulus* Leuckart 1892, *F. conjunctivæ*, Addario 1885, *F. taniguchi* Penel 1905, *F. immitis* Leidy 1856; *F. labialis* Pane 1864.

Filaria (Filaria) bancrofti Cobbold 1877.

Synonyms.—*Trichina cystica* Salisbury 1868, *nec* Rudolphi 1819; *F. sanguinis hominis* Lewis 1872; *F. sanguinis hominis ægyptiaca* Sonsino 1874; *F. dermatemica* da Silva Araiyo 1875; *F. wuchereri* da Silva Lima 1877; *F. sanguinis hominum* Hall 1885; *F. sanguinis hominum nocturna* Manson 1891; *F. nocturna* Manson 1891.

History.—The *Microfilaria* was discovered in Paris by Demarquay in August, 1863, in the chylocele fluid of a patient from Havana. In 1866 Wucherer found it in Brazil in the urine of patients suffering from chyluria. In 1872 Lewis made the important observation that its true anatomical habitat is the blood. Bancroft, in 1876, discovered the adult female form; Borne, in 1888, discovered the adult male. In 1899 Manson discovered that the *Microfilariæ*, on disappearing from the peripheral circulation, resorted to the lungs during the day-time. The parasite is spread by mosquitoes, as discovered by Manson in 1878, who at first thought that the *Filariæ* escaped from their insect hosts into water, and reached man by this means. Later he conjectured that *Filariæ* might be inoculated direct from the mosquitoes. To prove this hypothesis, he procured infected mosquitoes from Bancroft, of Brisbane, who had expressed a somewhat similar idea. Bancroft's material was investigated, at Manson's request, by Low, who discovered that the *Filariæ* migrate to the mouth-parts of their insect hosts after a period of growth within the musculature. A little later, independently, James made the same discovery in India. In the meantime Grassi and Noè investigated the life-history of a corresponding *Filaria* of the dog (*F. immitis*), and demonstrated that it undergoes a similar development also in mosquitoes, choosing, however, the Malpighian tubes instead of the thoracic muscles as the seat of their development. Moreover, Grassi and Noè were successful in inoculating normal dogs by means of mosquitoes fed on infected dogs. Fülleborn has most carefully restudied the subject.

Morphology—*General Characters.*—The worms are whitish in colour, long and filiform, with a smooth cuticle, and a globular head terminating in a simple, circular, unarmed, lipless mouth. The tail is rounded.

Sexual Characters.—The male is smaller than the female, and the only complete specimen measured 38·6 millimetres in length, and 0·12 millimetre in thickness. In the dead worm the tail is very much incurved, but may be straight during life, according to Maitland. The anus, which is 0·13 millimetre from the posterior extremity, is guarded by two projecting lips. The anal papillæ are not easily defined, but are said to consist of three pairs of pre-anal and three of post-anal papillæ.

There are two unequal curved retractile spicules. The larger measures 0·6 millimetre and the smaller 0·2 millimetre in length. They consist of a basal portion, which is broad, rigid, and chitinous, measuring 0·17 millimetre in the larger, and 0·12 millimetre in the smaller spicule, and a long, thin, colourless, cylindrical, slightly undulating terminal portion.

The female, while more or less transparent, is longer and thicker than the male, and measuring 76 to 100 millimetres in length, with a thickness of 0·185 millimetre.

The mouth is situated at the anterior extremity, being 8 μ in diameter, and leading into an œsophagus which passes insensibly into the intestine. This terminates in the anus, situated 0·28 millimetre from the incurved posterior end.

The vulva, situate 1·2 millimetres from the anterior extremity, opens into a single vagina, from which two uterine tubules run along most of the length of the body. These tubules contain the eggs and embryos in various stages of development.

Cobb's formula is:

$$\frac{-0{\cdot}36,\ 3{\cdot}64\ (?),\ 1{\cdot}22,\ 99{\cdot}5}{-0{\cdot}145,\ 0{\cdot}377\ (?),\ 0{\cdot}254,\ 0{\cdot}147}.$$

The numerator indicates lengths from the anterior extremity to (1) base of œsophagus; (2) nerve ring; (3) posterior pharyngeal constriction; (4) vulva in females or middle in males; (5) anus. The denominator represents transverse measurements at the same levels. All measurements are expressed as percentages of the total length.

Life-History.—The males and females may be found coiled together in the lymphatics of the scrotum, the arm, the leg, hydroceles of the cord, epididymis, or testicle, and more rarely in those of the pelvis and abdomen. The males are less numerous than the females.

When placed in saline solutions, they show active movements, coiling and uncoiling themselves for several hours.

In the uterus of the female, as has already been stated, eggs may be noted in all stages of development.

At first nearly round, measuring 50 by 34 μ, and containing a coiled-up embryo, the eggs become more and more elongated by the movements of the embryo, until in the anterior part of the uterus they are much longer than broad. Finally, they escape through the genital pore, and enter the lymph-stream, along which they travel through lymphatic vessels and glands, the thoracic duct, the right side of the heart, and the lungs, to reach the peripheral circulation, where they are best seen at night; hence the name *Microfilaria nocturna*. In the blood they appear as little wriggling filiform bodies, knocking the corpuscles about, but not moving from the position in which they are lying. The *Microfilaria* in the blood are said to be a little larger than those in the uterus, which is thought by Penel to be due, not to growth, but to imbibition of fluid by osmosis.

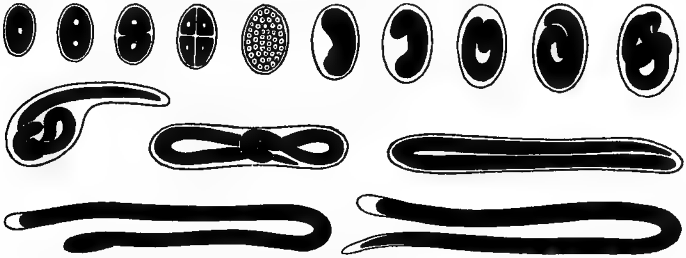

FIG. 154.—DIAGRAM OF THE DEVELOPMENT OF A MICROFILARIA (F. LOA STILES).
(After Penel.)

They measure from 130 to 300 μ in length, and from 7 to 11 μ in breadth, and are seen to be long, slender, cylindrical organisms with a rounded anterior and a tapering posterior end, enclosed in a sheath—the vitelline or egg membrane—inside which they are capable of darting backwards and forwards, because it is longer than they are, the empty portion being noted either in front of the anterior or behind the posterior end of the *Microfilaria*. Manson considers that this sheath is of vital importance to the little parasite, as it prevents its using its anterior spine to escape out of the bloodvessel, and so losing the chance of its invading a mosquito.

The anterior rounded extremity possesses a thick hemispherical proboscis, carrying a minute apical spine, which is capable of being covered by a retractile and protractile six-lipped prepuce.

Behind the anterior end, the body can be seen to be composed of a transversely striated dermo-muscular layer, inside which are a number of closely packed cells, whose nuclei show up clearly on staining. Unstained, the central mass appears granular, but the granules are, however, wanting at certain spots, which, following Annett, Dutton, and Elliot, may be defined as: (1) A clear anterior area from the front to the first nuclei; (2) an irregular transverse spot situated 21·5 per cent. of the length of the body from the anterior end; (3) a **V**-shaped or transverse irregular spot at 30 per cent. of the length, called **V**-spot by Manson; (4) a median line, the central viscus of Manson, whose centre is at 63 per cent. of the length; (5) an irregular oval spot often present at 85 per cent., called the tail-spot by Manson; (6) a small central spot only occasionally present at 91·5 per cent.; (7) the clear posterior area behind the last nucleus.

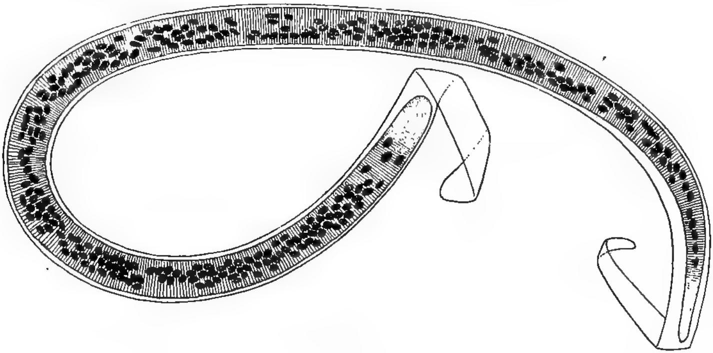

FIG. 155.—MICROFILARIA BANCROFTI COBBOLD.

The meaning of these clear areas is not evident. Manson thinks that the **V**-spot is the *Anlage* of the water vascular system and the tail-spot of the proctodæum, but the development of the worm has recently been studied in detail by Fülleborn, whose diagram is reproduced on the next page.

These *Microfilariæ* occur in the peripheral blood at night, as has just been stated, beginning about 5 to 7 p.m., and increasing in numbers till midnight, and then diminishing till about 7 to 8 a.m., when only a stray one may be met with, as, indeed, can be observed all through the day until the evening increase begins. There is, therefore, a definite periodicity—at night the *Microfilariæ* abound in the blood, while in the day-time they do not.

In the day it appears that they live mostly in the lungs and in the large vessels of the thorax. This was shown by Manson by the careful examination of films and sections taken from the different organs of a man who had *Microfilaria bancrofti* in his peripheral blood, as well as a lymph scrotum and varicose groin glands. The post-mortem was made six hours after death, which was due to drinking hydrocyanic acid, and took place almost instantaneously at 8.30 a.m. By far the largest number of parasites were to be found in the lungs and carotid artery, and then in the heart muscle, while a few were found elsewhere, especially in the kidney.

These facts have been confirmed, but the question as to what induces the parasites to live in the peripheral blood in the night and the thoracic organs in the day is not clear. True, it enables the *Microfilaria* to enter the mosquito, but that does not explain the problem. Neither variations in atmospheric temperature nor pressure, in light, or darkness seem to have any effect. Nor does the pulse-rate or the individual's temperature make much difference; but there is one factor, first shown by Mackenzie, and since confirmed by Manson and others, that it is in some way connected with sleep; for if a person with *Microfilariæ* in his blood stays awake all night, and sleeps during the day, the parasites will abound in his blood in the day, and not at night. Penel probably rightly remarks that the problem of the periodicity of the *Microfilaria* and the periodicity of sleep in man are connected, and that when one is properly solved the other will be also elucidated.

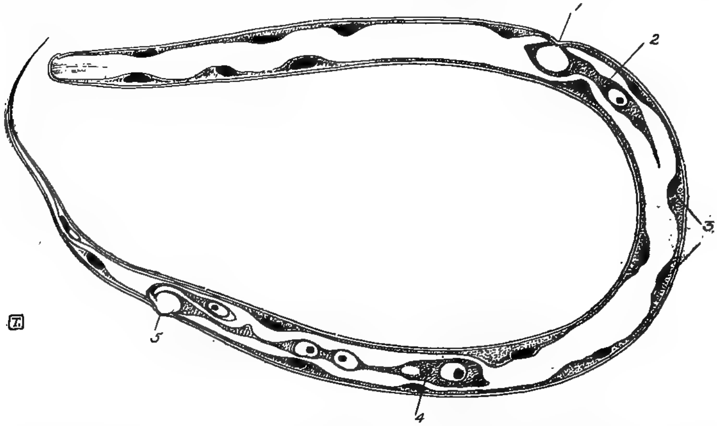

FIG. 156.—SCHEME OF THE STRUCTURE OF A MICROFILARIA, SHOWING (1) THE EXCRETORY PORE; (2) THE CELLS, WHICH WILL FORM THE EXCRETORY APPARATUS; (3) THE SUBCUTICULAR CELLS; (4) THE GENITAL CELLS; (5) THE GENITAL PORE.

(After Fülleborn.)

The number of *Microfilariæ* in the blood varies from very few up to quite considerable numbers, reaching, according to Manson, up to 500 in a single film, which gives some 40,000,000 to 50,000,000 in an average-sized man. This naturally raises the question of, How many adults do these come from? How long does an adult live? How long does a *Microfilaria* live? What finally happens to the *Microfilaria*?

These questions are much more easily asked than answered. It would seem probable that a given *Filaria* can live several years in the human body, and, of course, give rise to many embryos. Further, numbers of *Filaria* can be met with in one individual.

Bancroft thinks that the *Microfilaria* can live in the blood for several months, and observers have thought that they may be destroyed by leucocytes and endothelial cells. It is, however, evident that they develop no further in the human body, and require to be taken into the body of a mosquito before further development is possible.

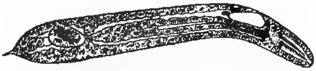

FIG. 157.—EARLY STAGE OF THE DEVELOPMENT OF FILARIA BANCROFTI COBBOLD IN THE MUSCLES OF CULEX FATIGANS.

(After Looss, from Mense's 'Tropenkrankheiten.')

In the Mosquito.—Abounding as they do in the peripheral blood at night, there is no difficulty for the *Microfilariæ* to reach the stomach of a mosquito in the tropics, and here and in its thorax development proceeds.

The mosquitoes known to be capable of serving as efficient hosts for this development are: *Culex fatigans* Wied in the West Indies, *Myzomia rossii* Giles in India, *Pyretophorus costalis* Loew in Nigeria, *Panoplites africanus* in Central Africa, *Stegomyia fasciata* in Nigeria.

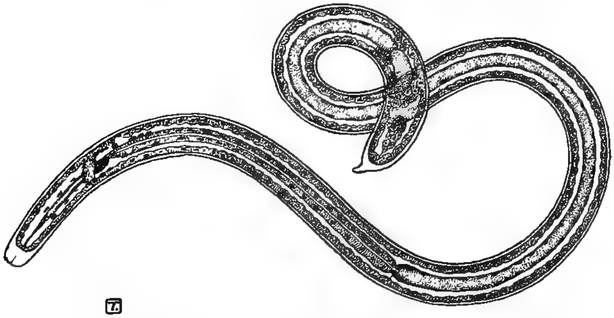

FIG. 158.—LATE STAGE OF THE DEVELOPMENT OF FILARIA BANCROFTI COBBOLD IN CULEX FATIGANS.

(After Looss, from Mense's 'Tropenkrankheiten.')

Incomplete results have been obtained with *Culex microannulatus*, *C. albopictus*, *C. tæniatus*, *Anopheles albimanus*; and negative results in *C. notoscriptus*, *C. annulirostris*, *C. hispidosus*, *C. vigilax*, *C. nigrithorax*, *C. procax*, *A. musivus*, *Myzomia funesta*, *A. maculipennis*, *Pulex serraticeps*, *Stomoxys* (?), *Cimex lectularius*.

The *Microfilariæ* enter with the blood into the mosquito's stomach, and there, the sheath being fixed by the hæmoglobin escaping from the red corpuscles, and becoming altered by the secretions of the stomach, they escape by rupturing it by means of the spine on their anterior extremity.

They then pierce the wall of the stomach, and find their way into the muscles of the thorax, where they grow considerably till 1·5 millimetres long and 0·25 millimetre broad.

They also undergo development, obtaining four lips, an alimentary canal, and a three-lobed tail. When so far developed, they leave the thorax and pass through the prothorax and head into the labium, where they remain until the mosquito bites a man, when they escape into the wound by making their way through Dutton's membrane, which is a thin membrane between the labella and the chitinous skeleton of the labium, as was demonstrated by Lebredo. (For further details see Chapter XXXV.)

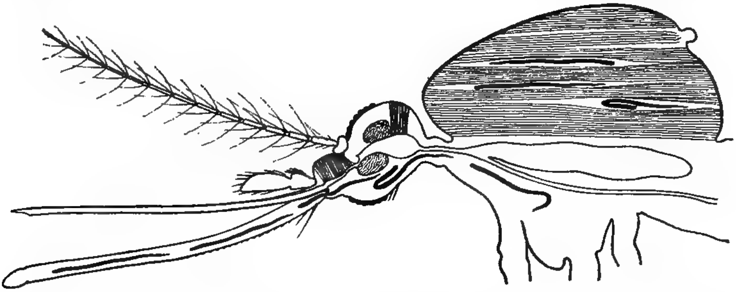

FIG. 159.—DIAGRAM OF THE DEVELOPMENT OF FILARIA BANCROFTI COBBOLD IN THE THORAX, HEAD, AND LABIUM OF A MOSQUITO.

Their further development in man is not known, but in due course they become adults.

Pathogenesis. — Usually non-pathogenic, these worms under certain circumstances can cause elephantoid fever, elephantiasis, lymph scrotum, etc., or, in other words, filiariasis.

Filaria (**Filaria**) **perstans** Manson 1891.

Synonyms.—*Filaria sanguinis hominis minor* Manson 1891, *F. sanguinis hominis perstans* Manson 1891, *F. ozzardi* (variety truncated) Manson 1897.

History.—The *Microfilaria* was first found by Manson in the blood of negroes from the Congo. Daniels found the adults in British Guiana. The geographical distribution known at present is Tropical Africa and British Guiana.

Morphology.—The adults are found, as a rule, free in the connective tissue at the base of the mesentery, around the pancreas, behind the pericardium, and behind the abdominal aorta and the suprarenal capsules. The body is cylindrical, uniform, except towards both ends, when it tapers a little.

The male, rarely met with, is 45 millimetres in length by 0·6 millimetre broad, with a greatly curved tail, which ends in a bifid prolongation of the cuticle. There is one large spicule, according to Penel, which terminates in a trumpet-shaped internal expansion continuous with the seminal tube. Low, however, describes two unequal spicules and four pairs of pre-anal and one of post-anal papillæ, all of which are very small.

The female is 70 to 80 millimetres in length and 0·12 millimetre in breadth, with a rounded head and a long neck. The incurved tail ends in two triangular cuticular lobes. The mouth is simple and small, and the alimentary canal shows no differentiation into œsophagus or intestine. The anus opens upon a papilla 0·145 millimetre in front of the tip of the tail. The uterus is double, and, when full of eggs and embryos in various stages of development, nearly fills the body. The vulva is 0·6 millimetre behind the anterior extremity.

Life-History.—The egg undergoes its development in the uterus, and the *Microfilaria* escapes from its egg membrane, and appears in the peripheral circulation without a sheath, and, consequently, can move about on a slide. It measures 200 to 230 μ in length and 4·5 to 5 μ in breadth. It is covered with a finely striated cuticle, and has a retractile spine, situated (apparently) upon a papilla at the anterior end of the body. The posterior two-thirds of the body tapers to the tip of the tail, which is abruptly rounded off.

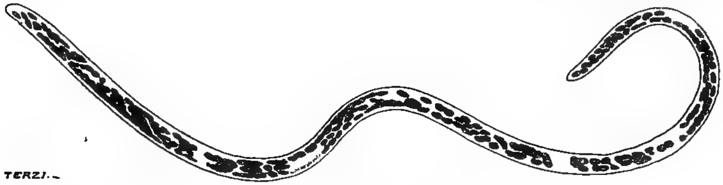

FIG. 160.—MICROFILARIA PERSTANS MANSON.

It does not appear to have the central viscus seen in *Microfilaria bancrofti*. In stained specimens there is an area free from nuclei anteriorly, a transverse break at 34 μ, a **V**-spot at 49 μ, and the tail-spot at 125 μ.

A short type, measuring 90 to 100 μ, has been noted. There is no periodicity in its appearance in the peripheral blood. It never occurs in large numbers, but it is always there day and night.

Many attempts have been made to trace its life-history. Its larvæ have been found in the thorax in *Panoplites* (*africanus ?*), *Stegomyia fasciata*, and *Tæniorhynchus fuscopennatus*. It will not develop in a large number of blood-suckers—*e.g.*, species of *Anopheles*, *Culex*, *Pulex*, *Pediculus*, and *Uranotænia*. Wellman and Feldham claim to have found its development in a tick (*Ornithodoros moubata*), as first suggested by Christy.

It is to be noted that it only occurs in areas covered with dense forest, and possessing swamps, which indicates that the host probably requires shade in the day and water to lay its eggs in.

Pathogenesis.—Nil.

Filaria (Filaria) demarquayi Manson 1895.

Synonym.—*Filaria ozzardi* Manson 1897.

In 1895 Manson discovered a *Microfilaria* in blood-films from natives of St. Vincent in the West Indies, which he named *Filaria demarquayi*, after the discoverer of the *Microfilaria bancrofti.* In 1897 he found in blood-films from Carib Indians of British Guiana another *Microfilaria*, which closely resembled *M. demarquayi*, but which he provisionally considered to be a different species, and called *F. ozzardi.*

Lately Penel and Manson have come to regard them as identical. In 1898 Daniels found the adult females.

It is found in St. Vincent, Dominica, Trinidad, St. Lucia, in the West Indies, and in British Guiana, where it is found in jungly districts. The adults live in the connective tissue at the root of the mesentery and elsewhere.

Morphology.—The male can hardly be said to be known, as only a fragment of a posterior end has been found, which showed a much incurved tail, with at least one spicule. The female measures 65 to 80 millimetres in length and 0·21 to 0·25 millimetre in breadth, with a bulbous cuticular expansion at the tip of the tail. Anus 0·25 millimetre in front of the posterior extremity, vulva 0·71 millimetre behind the anterior end.

Life-History.—The egg develops into a *Microfilaria* which has no sheath, shows no periodicity, and measures 200 μ by 5 μ. Its tail is tapering, and it moves actively. Nothing further is known as to the life-history.

Pathogenesis.—Nil.

Filaria (Filaria) magalhæsi Blanchard 1895.

Synonym.—*F. bancrofti* Magalhæs 1892, *nec* Cobbold 1877.

In 1887 Magalhaes described male and female forms of a *Filaria* found by Figeira de Saboia in the left ventricle of the heart of a child in Rio de Janeiro.

For a time it was mistaken for *F bancrofti*, but in 1894 Manson pointed out that it was a different species, and in 1895 Blanchard gave it the present name.

Morphology.—The worms were white, opalescent, and transversely striated, the head club-shaped and simple, mouth terminal, œsophagus with a bulb, and there was a rounded tail. The male measured 83 millimetres in length and 0·28 to 0·4 millimetre in breadth, and possessed a rounded tail, with a cloaca 0·11 millimetre from its tip, with two spicules and four pre-anal and three post-anal pairs of papillæ.

The female was 155 millimetres in length and 0·6 to 0·8 millimetre in breadth, with a vulval opening 2·56 millimetres behind the mouth, and an anal opening 0·13 millimetre in front of the tip of the tail.

Life-History and Pathogenesis.—Unknown.

Filaria (**Filaria**) **medinensis** Linnæus 1758.

Synonyms.—*Dracunculus veterum* Velsch 1674, *Vena medinensis* Velsch 1674, *Dracunculus persarum* Kämper 1691, *Gordius medinensis* Linnæus 1758, *Filaria dracunculus* Bremser 1819, *F. æthiopica* Valenciennes 1856, *Dracunculus medinensis* Cobbold 1864.

Filaria medinensis, commonly called the guinea-worm, the dracunculus, Beinwurm, Brachwasserwurm, tankworm, or dragonneau, is endemic in tropical Africa, India, Persia, Turkestan, Arabia, and some places in South America, in which it was imported from Africa.

It has been known since the most remote periods as it was probably the fiery serpent mentioned by Moses, who apparently knew the method of twisting the worm out on a stick, as he appears to have made a model of this method of extraction. Galen called the disease caused by these worms dracontiasis.

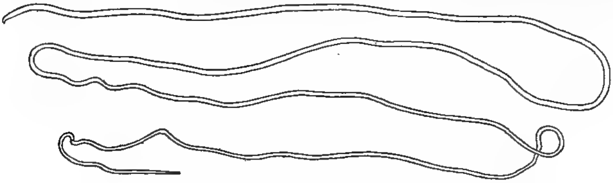

FIG. 161.—FILARIA MEDINENSIS LINNÆUS.

The anatomy of the worm was carefully studied by Bastien in 1863, and the infection of *Cyclops* with the larva was observed by Fedschenko in 1870, and confirmed later by Manson. Charles found the male guinea-worm in 1892.

Leiper 1907 has repeated these experiments, and has further proved that when monkeys are fed on infected *Cyclops* the males and females can be found. Strassen has confirmed Leiper's experiments.

Morphology.—The female is a long white filiform worm 50 to 80 millimetres in length and 0·5 to 1·7 millimetres in diameter.

The anterior end is bluntly rounded, and carries the small terminal mouth, which has two lips and two lateral and four submedian papillæ. It leads into a straight alimentary canal, which atrophies near the tail in the fully developed condition, and has no anal opening. The vulval orifice is situate close to the mouth, just external to the papillæ, and leads by a vagina into a large uterus, which occupies the whole length of the body when filled with embryos, and compresses the alimentary canal. The tail is rounded off, and carries a small bent hook.

The male is only 22 millimetres in length, and has five pairs of post-anal papillæ.

Life-History.—The males and females live in the connective tissue about the mesentery, and after copulation probably the males die off. When the female is gravid, she moves, head first, apparently in search of water, usually downwards towards the leg or foot; but in other cases—*e.g.*, Indian water-carriers—to the back. More rarely she moves to the hand or arm, and very rarely to the head. Arrived under the epidermis, she bores her way through the deep layers, while a little bulla on the surface marks her presence.

When this bulla bursts, a small hole is seen, at the bottom of which lies the vulva, through which the tube of the uterus has prolapsed, bending the head to one side. Clear fluid can be seen escaping from this tube, which, when examined, is found to be full of embryos.

The segmentation of the egg takes place in the uterus, and the embryos are born alive. They are flat, pointed little bodies, 0·6 millimetre in length and 17·5 μ in breadth, with a narrow, very pointed tail. The mouth is at the anterior end, and leads into an alimentary canal without an anus. There is a little sac on each side of the root of the tail. These little larvæ swim about vigorously, and either die or enter the alimentary canal of a *Cyclops* by passing through the mouth into the intestine, from which they enter the cœlom, where they develop for four weeks. The first ecdysis takes place about the seventh to ninth day, and the second between the tenth and eleventh day, after which progressive histological changes occur. After the fourth week no further change takes place, though they can live for forty-one days in the *Cyclops*. When placed in 0·22 per cent. solution of hydrochloric acid, the *Cyclops* is promptly killed, while the larva appears to be stimulated, undergoing ecdysis, and escaping from the *Cyclops* by boring its way through the chitinous cuticle. In a monkey fed by Leiper with infected *Cyclops*, two females and one male were found. It is, therefore, correct to assume that man is infected by ingesting infected *Cyclops* with his drinking-water, and it is probable that, set free in the stomach, the larvæ enter the connective tissue by boring their way through the stomach-wall.

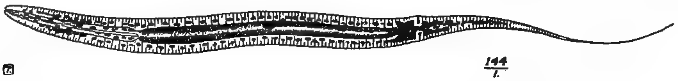

FIG. 162.—LARVA OF FILARIA MEDINENSIS LINNÆUS.

(After Looss, from Mense's 'Tropenkrankheiten.')

Pathogenesis.—The worm causes dracontiasis (see p. 1054).

Filaria (Filaria) volvulus Leuckart 1893.

This worm was discovered by a German medical missionary in two tumours on the scalp and chest of negroes in the Gold Coast Colony, West Africa. Labadie, Lagrave, and Deguy found another specimen in a small swelling in the arm of a soldier from Dahomey. Prout next described two cases in Sierra Leone, and Brumpt a number of cases in his tour in West Africa, and recently Fülleborn has thoroughly studied the condition produced by the worm in man.

It is found in Sierra Leone, Gold Coast, and Dahomey; but on the Welle, between Dongon and M'Bini, it is said to occur in 5 per cent., and on the Itumburi, between Bonta and Idembo, in 1 per cent. of the population. It has not been recorded as far south as the Congo.

Morphology.—The male worm has a white filiform body, slightly attenuated at the ends, covered with a transversely striated cuticle, measuring 30 to 35 millimetres in length and 0·14 millimetre in breadth.

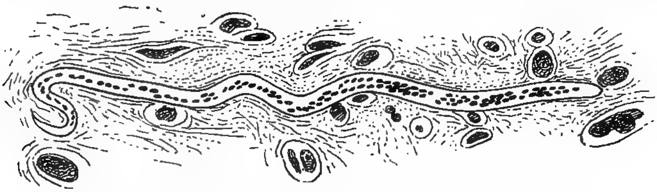

FIG. 163.—MICROFILARIA VOLVULUS LEUCKART. (After Fülleborn.)

The head is rounded, the mouth unarmed, the alimentary canal straight and undifferentiated, the anus subterminal 0·049 millimetre in front of the posterior end. Other canals are reported which probably belong to the generative and excretory systems.

The tail is strongly recurved, and somewhat flattened on its concave aspect. Brumpt reports three pairs of papillæ on each side of the anus and three pairs of post-anal papillæ. There are two unequal spicules, the larger 177 μ and the smaller 82 μ in length.

The female is longer and thicker than the male, measuring 60 to 70 millimetres in length, and 0·36 millimetre in breadth. The cuticular striations are not so well marked. The tail is recurved. The uterus is seen full of eggs and larvæ, and the vulva is 0·76 millimetre from the anterior end.

Life-History.—The worm lies in a lymphatic, which becomes inflamed, and a perilymphangitis causes a condensation of connective tissue, in which males and females are embedded, leaving the posterior end of the male and the anterior end of the female free in the lymph space. The embryos pass out of the uterus into this space where they can be found 250 to 300 μ in length, and 5 to 6 μ in breadth, with a rounded head and a body which tapers during the last fifth, and terminates in a pointed tail. There is no sheath. The anterior **V**-spot is clearly seen. The *Microfilaria* have not been seen in the blood, and their further development is quite unknown.

Brumpt is inclined to think that they will be found in the blood, and that the further development will be in a tsetse-fly. The adults live for years in the human body.

Pathogenesis.—Lymphangitis, perilymphangitis, sometimes acute and with fever, and resulting in small tumours, are their pathological signs.

Filaria (Filaria) conjunctivæ Addario 1885.

Synonyms.—*F. peritonei hominis* Babes 1880, *F. inermis* Grassi 1887, *F. apapillocephala* Condorelli Francaviglia 1892.

This worm was first discovered by Dubini in the eye of a man in Milan, then by Babes in the gastro-splenic omentum of a woman in Budapest, then by Vadela in the conjunctiva of a woman in Sicily. Perhaps *F. palpebralis* Pace 1867 and *F. oculi humani* van Nordmann belong to this group. It is possible that this is the common *Filaria* seen in the eyes of horses in India and Ceylon, and which is usually confounded with *F. equina* Abildy 1789; if so, the horse would be the normal host. It is possible that the *F. loa* described in India was one of these parasites.

Morphology.—Only the female is known, and it is white in colour, and measures 16 to 20 centimetres in length and 0·5 millimetre in breadth. The cuticle is striated except just around the mouth, but there are neither papillæ nor lips. The anus is subterminal, and the vulva close behind the mouth. There is a single vagina and a double uterus containing eggs and embryos.

Life-History and Pathogenesis.—Unknown.

Filaria (Filaria) taniguchi Penel 1905.

This *Filaria* was found in a lymphatic gland from a person living in Ama Kusha in Japan. Only the female and the *Microfilaria* are known.

The former measured 68 millimetres in length and 0·2 millimetre in breadth, and had a non-striated cuticle, a terminal mouth with two pairs of papillæ, an anus 0·23 millimetre in front of the posterior extremity, and a vulva 1·3 millimetres behind the mouth.

The latter measured 164 μ long by 8 μ broad, possessed a sheath and a truncated tail, and showed a nocturnal periodicity.

Life-History.—Not known.

Pathogenesis.—Nil.

Filaria (Filaria) immitis Leidy 1856.

This worm lives in the right heart and in the veins of the dog, and also the wolf and the fox, in Europe and tropical regions. It is very common in China and Japan.

Bowlby is commonly reported to have found this worm in the portal vein, kidneys, bladder, ureters, and lungs of an Arab, and also in a rectal tumour in a youth, but this is quite erroneous, as he never made any such statement, for the eggs in the bladder and rectum, and the parasites in the portal vein of the Arab, were *Schistosomum hæmatobium*, as he carefully reported, never mentioning *F. immitis*. Braun, however, seems to think it possible that this worm may occur in man.

Morphology.—The worm is long, measuring 12 to 18 centimetres by 0·7 to 0·9 millimetre in the male, and 25 to 30 centimetres by 1·0 to 1·3 millimetres in the female, and filiform, with a smooth rounded cuticle and a rounded anterior extremity, on which is situated the terminal mouth with six small papillæ. The anus is subterminal, and the posterior extremity pointed.

The male has a twisted tail with a cuticular fold on each side, and four pre-anal and post-anal papillæ. In the female the vulva is 7 millimetres from the anterior extremity. Viviparous.

Life-History.—The young larvæ, 285 to 295 μ by 5 μ, are not enclosed in an egg-case, and have a tapering posterior extremity. They appear in the peripheral blood particularly at night, when they may enter a mosquito if it bites the dog.

They enter the Malpighian tubules or their epithelial cells, where they moult and grow, eventually passing via the body cavity to the labium.

They escape through Dutton's membrane into the wound formed when the mosquito bites, and so enter the dog,

Filaria (Filaria) labialis Pane 1864.

This parasite was extracted from a small pustule on the inner surface of the upper lip of a person in Naples in 1864, and was not again described until Pierantoni, in 1908, again found it occurring in Naples. In both cases the female has been found, varying from 130 to 30 millimetres in length, with a whitish-yellow body, and a pointed anterior extremity, on which the terminal mouth, guarded by four papillæ, opens. The anus opens 150 μ anterior to the posterior end, and the vulva opens 3 millimetres behind the anterior extremity. The uterus bifurcates into two branches.

Subgenus Loa Stiles 1905.

Filariinæ with bosses on the cuticle and with caudal papillæ.

Species.—*Filaria (Loa) loa.*

Filaria (Loa) loa Cobbold 1864.

Synonyms. — *Filaria oculi* Gervais and van Beneden 1859, *Dracunculus oculi* Diesing 1860, *D. loa* Cobbold 1864, *F. subconjunctivalis* Guyon 1864.

The larval names are: *F. sanguinis hominis var. major* Manson 1891, *F. diurna* Manson 1891.

History.—That a *Filaria* occurred in the eye appears to have been known since the end of the sixteenth century in Europe; and probably in Africa, especially in Angola, where it was called 'loa'; that knowledge must have been very ancient. Mongin in 1770 appears to have been the first person to record the presence of a worm in the eye. Guyot, in 1778 and 1805, thought it was a *Strongylus*, and used the term 'loa' for the first time in European literature. In 1891 Manson found a *Microfilaria* in the blood of several negroes from the Congo which differed from those already described, and which he named *Filaria (Microfilaria) diurna*, and further suggested that it might be the larva of *F. loa*. Since then this hypothesis has been proved to be correct by the observations of Penel, Prout, Henly, Brumpt, Wurtz and Kerr. *F. loa* and *Microfilaria diurna* are, therefore, simply different stages in the life-history of the same parasite.

F. loa is a parasite of the superficial connective tissue—the conjunctiva, the subcutaneous fat, and the superficial aponeuroses in all parts of the body. It probably only occurs in man, for its alleged existence in sheep and goats in the Cameroons requires further investigation. Its endemic area is on the West Coast of Africa, from Sierra Leone to Benguela, being most common in Old Calabar, the Cameroons, and the Ogomé River. It is, however, by no means confined to the coast, for it is known to penetrate at least 600 miles into the interior of Africa.

The cases reported from India must refer to *F. equi*, and the cases from the West Indies and South America appear to have all been imported from the West Coast of Africa.

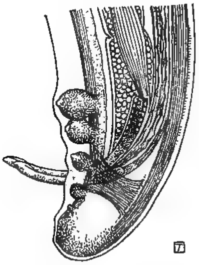

FIG. 164.—FILARIA LOA COBBOLD POSTERIOR EXTREMITY OF THE MALE.

(After Looss.)

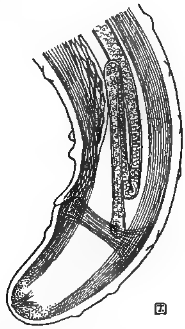

FIG. 165.—FILARIA LOA COBBOLD POSTERIOR EXTREMITY OF THE FEMALE.

(After Looss.)

The parasite appears to have never become endemic outside a given area, which means that the animal by which it is spread has a restricted geographical range.

Morphology.—The male is a thin, white, almost transparent worm, with a body tapering to each extremity, and measuring 25 to 34 millimetres in length and 0·273 to 0·430 millimetre in breadth. The head is like a truncated cone; the neck is but feebly indicated. The tail, more or less incurved, has a rounded tip, from which the anus is distant 74 to 82 μ. There are three pairs of well marked pre-anal and two pairs of post-anal papillæ, with sometime a little tubercle on each side of the middle line far posteriorly.

The spicules are two in number, and unequal, and are usually stated to differ but little in length. Penel says that the larger i traversed by a fine canal, opening laterally a little distance from th free extremity.

The cuticle consists of a superficial, thin, translucent layer an a deeper perpendicularly striated layer. Scattered over this cuticle there are rounded thickenings, or bosses, the smaller being 9 to 11 μ and the larger 14 to 16 μ in height. The thickness at the posterior extremity is variable, as also is the constriction corresponding to the neck. The viscera are enclosed in a cylindrical musculocutaneous tube. The mouth is terminal, small, unarmed, and surrounded by a powerful muscular cone ; the œsophagus is short, and without a bulb ; the intestine opens via the rectum at the anus, near the posterior extremity. The excretory pore is 0·65 millimetre from the anterior end of the body.

The genital apparatus consists of a tubular testis and vas deferens, filled with spherical spermatozoa, which terminates in a vesicula seminalis situate in the neighbourhood of the bases of the spicules.

The female is larger and thicker than the male, measuring in the fresh condition 44 to 63 millimetres (may be from 32 to 57 millimetres in different conditions of preservation) in length, and from 0·38 to 0·49 millimetre in thickness. The cuticle and anterior extremity resemble those of the male.

The genital system consists of a vulva situated on a little elevation 23 μ in height, and distant some 2·5 millimetres from the anterior extremity. This vulva leads into a thick-walled canal—the vagina—from which the two uterine tubes full of embryos and eggs diverge, and end in the ovaries.

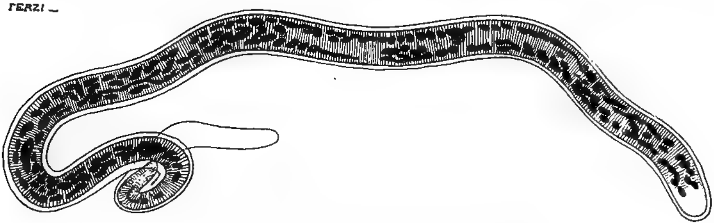

FIG. 166.—MICROFILARIA LOA COBBOLD.

Life-History.—The life-history, unfortunately, is not well known. The unsegmented egg, starting in the uterus with a length of 32 μ and a breadth of 17 μ, grows into 40 by 25 μ in the morula stage, and 50 by 25 μ in the stage when a twisted and rolled-up embryo can be seen. It now approaches the vulva, and the embryo unrolls and elongates itself inside the egg membrane, which is now considerably lengthened, measuring 250 to 260 μ in length by 5·5 to 6·6 μ in breadth. The embryo now escapes from the mother, and passes via the lymph-stream into the blood, where it is known as *Microfilaria loa* (*diurna*), and is noticed to have increased somewhat in size, which Penel considers is due to imbibition of fluid by osmosis, and now measures 298 by 7·5 μ. It will be noted, however, that it does not quite fill up its sheath, which is generally empty in front and behind for a short space. These embryos are only to be found in the peripheral blood during the day, and not at night, but they have no relation to sleep in the host like *M. bancrofti*, as the are unaffected by altering the habits of the host, and making hin sleep in the day and work at night. When examined under th microscope, they can be seen in irregular curves, which are differen from the graceful curves of *M. bancrofti*. The anterior **V**-spo can be seen, and probably opens at the apex to the exterior, a Penel has observed that the stain penetrated easily at that spot probably there is also an opening at the tail-spot also. In staine specimens the first 8 μ is clear, without nuclei; at 62 μ the colum of nuclei is broken by an irregular transverse spot; at 99 μ by triangular spot; at 253 μ by a large, and at 267 μ by a small spot. The last nuclei are arranged in single file. One noticeabl thing about these embryos is the scarcity with which they are me with in the peripheral blood as compared with *M. bancrofti*. N explanation of this is forthcoming at present.

It has been thought by Manson that the further stages of th life-history will be found in the mango-fly (*Chrysops dimidiatus*) but others suspect not merely Tabanidæ, but *Glossinæ* and *Stomoxys* in any case, the matter is purely conjectural at present.

After entering the human body, it would appear probable tha the worm takes some three to four years to reach maturity, an that it is long-lived — *i.e.*, fifteen or more years. The reason fo believing this is the fact that immature forms may be noted i children and the fully grown worm found in the adult. When th worm dies, it may become cretified.

Pathogenesis.—It may be noted under the skin of the finger, th back, the breast, the penis, the eyelid, under the conjunctiva, th mucosa of the tongue. It moves quickly, and may cause itching creeping sensations, so-called Calabar swellings, irritation of th eyes and of the glottis (see Chapter LII., p. 1046).

Subgenus Hamularia Treutzler 1793.

Synonym.—*Tentacularia* Zeder 1800, *nec* Bosc 1797.

Filaria with chitinous ring and papillæ around the mouth.

Filaria (Hamularia) equi Gmelin 1789.

Synonyms.—*Gordius equinus* Abbild 1789, *Filaria equi* Gmelin 1789, *Hamularia lymphatica* Treutzler, *Tentacularia subcompressa* Zeder 1800, *Filari papillosa* Rudolphi 1802, *F. hominis bronchialis* Rudolphi 1829, *F. homini* Diesing 1851, *Strongylus bronchialis* Cobbold 1879.

History.—*Hamularia* is frequently found in horses and asses, generall in the abdominal cavity, but also in the liver, female genitalia and cranium.

It is doubtful whether the immature *Filariæ*, so commonly met with i horses' eyes in India and Ceylon, belong to this species. It was first found i human beings by Treutzler in an enlarged bronchial lymphatic gland. Othe cases have been noticed by Blanchard, Brera, and von Linstow.

Morphology.—Whitish filiform body pointed posteriorly. Cuticle with delicat transverse striata, and mouth small, round, with chitinous ring and two lips and papilliform processes dorsally and ventrally, and two sub-median papillæ

Male 6 to 8 centimetres in length, with posterior extremity spiral, wit four pre-anal and four post-anal papillæ, and two unequal spicules.

Female 9 to 12 centimetres.

Pathogenesis.—Nil.

Microfilaria Le Dantec.

A collective group of the larvæ of unknown adult Filaridæ found in the blood of man and other vertebrates.

Filaria (Microfilaria) powelli Penel 1905.

This *Microfilaria* was found by Powell in 1903 in the blood of a Bombay policeman.

It showed a nocturnal periodicity(?), was provided with a sheath, measured 131 μ by 5·3 μ, and had a truncated tail.

Filaria (Microfilaria) philippinensis Ashburn and Craig 1906.

Ashburn and Craig described this blood filaria in May, 1906. It measures 0·29 to 0·335 millimetre in length, has no periodicity, is actively and progressively motile, and is enclosed in a tight-fitting sheath, within which it cannot slip backwards and forwards, and which is only clearly seen at the extremities. The anterior extremity is broad, with a serrated prepuce, and supports a small retractile spicule. The body has an outer striated musculo-cutaneous coat and an inner clear portion, with an anterior **V**-spot situate 0·105 millimetre from the anterior end, and piercing the outer coat by its apex, and opening on the surface.

The central viscus is seen as a convoluted or spiral tube in the posterior part of the middle third of the body. The tail-spot is in the centre of the posterior third of the body, and opens by the apex of its **V** on the surface, where there is a distinct papilla. The tail begins to taper at a point midway between the tail-spot and the posterior end, and ends in a fine threadlike point. It is thought that this end disappears during later development.

The column of nuclei runs the whole length of the worm, being broken by unstained areas here and there. In stained species the **V**-spots and central viscus are not seen.

Life-History.—This *Microfilaria* develops in *Culex fatigans* Wied. On entering the stomach of the mosquito, it escapes from its sheath within twenty-four hours, and has pierced the stomach-wall and appeared free in the cœlom, where many die, but others develop rapidly, and complete their mosquito cycle. Generally by the third day they have left this position and travelled into the thoracic muscles, where they develop. At first there is a decrease in length from 0·32 to 0·21 millimetre, but an increase in breadth from 0·0065 to 0·01 millimetre.

By the eighth day the *Filaria* has increased in length and breadth, and shows an alimentary canal along its whole length.

From this till the eleventh day the development is rapid, and the worm now measures from 1·2 to 1·6 millimetres in length by 0·04 to 0·02 millimetre in breadth, and has a mouth, œsophagus, chyle intestine, and an anus, and the tail has three well-defined papillæ.

From the eleventh to twelfth day the worms are found in the head, and by the fourteenth to fifteenth day in the labium, lyin side by side, with their heads pointing forwards.

As many as four can be seen in this position. In the labium the have diminished in width and increased in length. They no show two tubes running parallel with the alimentary canal, whic are probably the *anlage* of the generative glands.

Agamofilaria Stiles 1906.

A purely collective group, to contain agamic forms of Filariid which have not yet reached a stage in their development permitting their being generically determined.

Species.—*Agamofilaria georgiana* Stiles 1906, *A. oculi* Diesin 1851, *A. palpebralis* Pace 1867.

Agamofilaria georgiana Stiles 1906.

These immature *Filariæ* were obtained by Graham from a sore o the leg of a negress at Darien.

They were cylindrical in shape, with a more or less unifor diameter, gradually attenuating towards both extremities. Mout terminal, central, circular, small, unarmed, and surrounded b six papillæ, four of which were prominent and sub-median; tw were smaller and latero-median. Anus a transverse slit, situate from 64 to 128 μ from the posterior end. Tip of the tail, wit conical projections, 8 to 13 μ in length by 4 μ in breadth Excretory pore 0·432 to 0·520 millimetre from anterior end.

Cuticle without striation, except some very fine transverse line near the anus. Median lines visible in glycerine specimens. Latera bands rather prominent, with longitudinal, sinuous ridges hanging into the body cavity, and with longitudinal canal emptyin into excretory pore. Œsophagus simple, 2·5 to 2·9 millimetres i length, triradiate on section. Chyle intestine straight. Rectu 200 μ long. Body-cavity almost completely occupied by th intestine, lateral longitudinal glands, and reticular formation which is probably the primordium (*anlage*) of the genital apparatus

Agamofilaria oculi von Nordmann 1832.

Synonyms.—*Filaria oculi humani* von Nordmann 1882, *F. lentis* Diesin 1851.

These are immature filarial worms, found in cataracts by von Nordmann Gescheidt, and Kühnt. Braun rejects those by Quadri, Fano, Schoeler, an Everbusch. The common error here appears to be to mistake the remains o the hyaloid artery for a parasite. The worms measured from 0·38 millimetr up to 12·6 millimetres in length.

Agamofilaria palpebralis Pace 1867, *nec* Wilson 1844.

This *Filaria* was removed from a tumour in the upper eyelid of a boy.

FAMILY 6. MERMITHIDÆ.

Nematoda with a diagonal fibre system in the cuticle, without anus, an with six mouth papillæ.

The male has two spicules and three rows of numerous papillæ.

Genus.—*Mermis.*

Mermis.

Mermithidæ possessing the characters of the family.

Subgenus Agamomeris.

A purely collective group, which contains forms sexually immature and not capable of being definitely placed.

Agamomeris restiformis Leidy 1880.

Synonym.—*Filaria restiformis* Leidy 1880.

In 1880 Leidy received from Woodward a worm which was supposed to have come from the urethra of a man living in America. Stiles has re-examined this specimen, and concludes that it is an Agamomeris.

The cuticle is 32 to 48 μ thick, with a diagonal fibre system. The head end is attentuated, and possesses a very small terminal mouth without lips, behind which are six papillæ. The excretory pore (?) is 0·442 millimetre behind the mouth. The pharynx is straight, and opens into the cylindrical intestine, which is a dark cæcal structure; but there is no anus and no caudal papillæ. The tail is curved ventrally and bluntly rounded.

On one side of the œsophagus there is a blind sac, which probably represents the fat body.

Filaria (?) *hominis oris* Leidy 1850.—Perhaps this worm ought to be classified here instead of under Filaria.

FAMILY 7. TRICHINELLIDÆ.

Nematoda with the anterior portion of the body thin and whip-like; posterior portion thick with genitalia. Mouth small, without papillæ. Œsophagus very long, traversing a peculiar strand of cells.

Genera.—*Trichinella, Trichuris.*

Trichinella Railliet 1895.

Synonym.—*Trichina* Owen 1835, *nec* Meigen 1830.

Very small Trichinellidæ, with thin, hair-like bodies. Posterior end of the male with two cone-like appendages, between which the cloaca is situate. Vulva placed far forwards.

Trichinella spiralis Owen 1835.

Synonym.—*Trichina spiralis* Owen 1835.

T. spiralis, though discovered by Paget in 1835 and described by Owen, had been previously seen by Peacock in 1828 and by Hilton in 1833.

It is really a parasite of the black rat (*Mus rattus*) and the sewer rat (*M. norvegicus*), in which the rate of infection is placed from 8·3 to 100 per cent., according to the locality, but it spreads from the rat to pigs, dogs, cats, and many other animals.

Man becomes infected from the pig as a rule, for that animal is particularly liable to the disease, because it is apt to be fed upon scraps of raw meat. Further, the larva in the flesh of the pig is very difficult to kill, for it will resist a temperature of 80° C., pickling, smoking, and freezing. Hence, though ham be well boiled, it does not follow that the larvæ in its centre are killed. Sausages, however, are the greatest danger, for in them the larvæ can live well protected.

In order to infect man, there must be a source of infection for the pig, and this, in the first instance, can come from the rat, and afterwards be kept up in the pig, and then the transmission to man is easy.

As rats, pigs, and men are cosmopolitan, so trichiniasis is also cosmopolitan. It is not uncommon in certain parts of India, and is known in China. In considering the endemicity of the disease, it must not be forgotten that the wild boar (*Sus scrofa ferox*) is susceptible. The disease is supposed to hav been introduced into Europe from Asia, either by *Mus norvegicus* at the en of the eighteenth century, or by the Chinese pig from 1820 to 1830. A present it is common also in America.

Morphology and Life-History.—It is usually found in human or pig muscles, where it appears as minute white specks, which, when magnifie are found to be encysted larvæ. These cysts are oval, with their long axi in the same direction as that of the muscular fibres, measuring 400 by 250 μ The cyst membrane is formed from inflamed connective tissue, which ha invaded the infected muscular fibre. Inside the cyst is the coiled-up worm In this condition the larvæ may live for years, but may be killed by calcification. They are mostly found in the diaphragm, the larynx, tongue, abdominal and intercostal muscles.

When these cysts reach the stomach of a man or animal, the gastric juic dissolves the cyst-wall, and the parasites escape, and, entering the duodenu and jejunum, they grow into adult males 3 to 4 millimetres long by 60 μ i diameter, and females 1·4 to 1·6 millimetres long by 40 μ in diameter, whic copulate. The males now die off, and the females, increasing in size, penetrat the mucosa of the bowel until they reach a lymph-channel, in which they deposit their larvæ, which are born alive. Leuckart says one female gives ris to 1,500 larvæ, which are carried by the lymph and blood streams all over th body. The larvæ now leave the capillaries, and work their way into th tissues, and in about nine to ten days encapsule in the muscles, the attacked fibres of which degenerate and become inflamed, and the cyst already described is formed.

Pathogenesis.—When the female pierces the mucosa, and during the wandering through the lymph and blood of the larvæ, very severe symptoms called trichinosis or trichiniasis are produced.

Trichuris Büttner 1761.

Large Trichinellidæ, with the anterior part of the body very long and thread-like, and the posterior thicker portion sharply truncated, with a terminal anus. Male with a spirally-rolled posterior end and one spicule ; female with one ovary, and the vulva situated at the junction of the thinner and thicker parts of the body.

Species in man : *Trichuris trichiura.*

Trichuris trichiura Linnæus 1761.

Synonyms.—*Ascaris trichiura* L. 1771, *Trichocephalus hominis* Schrenk 1788, *T. dispar* Rudolphi 1801.

This worm is very commonly met with in the tropics. Its eggs appear in the fæces, and it is met with in the cæcum and sometimes in the vermiform appendix during post-mortems. Its anterior end is frequently found buried in the mucous membrane, and while in this position it is possible for bacteria to enter and cause disease—*e.g.*, appendicitis.

It is commonly called the whip-worm, and is cosmopolitan in its distribution.

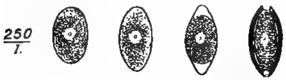

Fig. 167.—Development of the Egg of Trichuris trichiura.

(After Stiles.)

Morphology.—The male measures 40 to 45 millimetres in length, and is easily recognized by the spirally coiled posterior end. Its spicule, which lies in a retractile pouch, measures 2·5 millimetres.

The female measures 45 to 50 millimetres in length. The ova are oval, brown, thick-shelled, with a pale, clear body at each pole, where the shell is deficient. They measure 50 to 54 by 23 μ.

Life-History.—When the egg appears in the fæces, it is unsegmented, and is said to take eighteen months before the embryo is fully developed. The egg with the enclosed embryo is then taken in through the mouth in contaminated food or water, there being no intermediate host. The shell is dissolved by the gastric juice, and the embryo reaches maturity in the intestine in about four to five weeks.

Pathogenesis.—Usually harmless, but may give rise to intestinal disturbance and at times appendicitis.

FAMILY 8. STRONGYLIDÆ.

Nematoda with cylindroid, rarely filiform bodies, mouth usually with six oral papillæ, with or without chitinous armature, and an œsophagus more or less enlarged posteriorly. Male with a bursa copulatrix and one or two equal spicules. Female with a single or double ovary; vulva situated anteriorly or posteriorly. As a rule, the species are small. Oviparous or ovoviviparous.

This family contains a large number of genera—*Dioctophyme*, *Strongylus*, *Metastrongylus*, *Trichostrongylus*, *Agchylostoma*, *Necator*, *Triodontophorus*, *Œsophagostoma*, *Physaloptera*—which have been grouped by Railliet into three subfamilies:

1. *Dioctophyminæ* (*Eustrongylinæ*).—Mouth unarmed, bursa without ribs or bands (*Dioctophyme*).
2. *Strongylinæ*.—Mouth unarmed, bursa with ribs or bands (*Strongylus*, *Metastrongylus*, *Trichostrongylus*).
3. *Sclerostominæ*.—Mouth armed, bursa provided with ribs (*Agchylostoma*, *Necator*, *Triodontophorus*, *Œsophagostoma*, *Physaloptera*).

SUBFAMILY DIOCTOPHYMINÆ Railliet.

Strongylidæ with unarmed mouth, *Bursa copulatrix* without ribs or bands. Genus *Dioctophyme*.

Dioctophyme Goeze.

Very large Strongylidæ with cylindrical bodies; mouth with six papillæ Male with collar-like bursa and one spicule. Female with one ovary; vulva in the anterior half of the body.

Dioctophyme renale Goeze 1782.

Synonyms.—*Ascaris canis et martis* Schrenk 1788, *A. visceralis et renalis* Gmelin 1789, *Strongylus gigas* Rudolphi 1802, *Eustrongylus gigas* Diesing 1851, *Strongylus renalis* Moquin-Tandon 1860, *Eustrongylus visceralis* Railliet 1885.

This worm lives in the pelvis of the kidney in the dog, seal, otter, and wolf. It has been recorded twelve times in man, if the records really refer to this worm.

Morphology.—The worm is blood-red in colour, but otherwise very like a large *Ascaris lumbricoides*. Along the lateral lines there are about 150 papillæ. The submedian ridges are well developed, and the anterior extremity somewhat attenuated. Cuticle finely striated transversely.

Male 40 centimetres long by 4 to 6 millimetres broad; bursa without rays, and with one very long, slender spicule 5 to 6 millimetres in length. Female

100 centimetres in length and 12 millimetres in thickness, with an obtus slightly curved posterior end, a single ovary, and a vulva situate 50 to 70 mill metres behind the anterior extremity. Eggs ovoid, with thick, brownis shell 68 to 80 μ by 40 to 43 μ, with numerous depressions.

Life-History.—Development begins in the uterus of the female, but sto at a certain stage, and does not continue (Balbiani) until brought into contac with water or damp soil, when the egg hatches. The embryo is 240 μ by 14 cylindrical, and gradually tapering posteriorly. The head is pointed, with terminal mouth without papillæ, but which is thought to be provided with small protractile dart. The further development is not known; it has bee thought that it takes place in fish, but experiments have failed to justif this view.

Pathogenesis.—It is usually found in the kidney, which it destroys. I animals it has also been found in mammary and perineal tumours. Symp toms appear to be hæmaturia, and the diagnosis is made by the discovery o the eggs.

SUBFAMILY: STRONGYLINÆ Railliet.

Strongylidæ with unarmed mouth and bursa copulatrix with ribs or bands

Genera.—*Strongylus, Metastrongylus, Trichostrongylus.*

Strongylus Müller.

Mouth nude or provided with papillæ. Œsophagus dilated posteriorly Male with well-developed bursa copulatrix, supported by a variable numbe of ridges and provided with two equal-sized spicules. Females with the vulv situated in the posterior half of the body.

Strongylus gibsoni Stephens 1909.

This worm was discovered by Bell in the fæces of a Chinaman in Hon Kong, and described by Stephens.

Morphology.—The male measures 21 millimetres by 0·4 millimetre, an possesses an attenuated head with two cervical papillæ, and a mouth wit two lateral papillæ. The bursa shows two well-marked lobes, continue dorsally on to the body as a V-shaped slit. There is one pair of ventral rays and six pairs of dorsal rays—an anterior, two middle, and two posterior which last arise from a common stem. The spicules are very long (7 milli metres) and delicate.

The female measures 25 millimetres long, and possesses a pointed tail, o which the anus opens 0·2 millimetre from the tip, while the genital pore i 0·5 millimetre from the same extremity. The uterine egg measures 110 by 53 μ.

Life-History.—Nothing is known as to the life-history.

Pathogenesis.—It is not stated whether it is or is not pathogenic.

Metastrongylus.

Mouth with six small papillæ. Male with a bursa copulatrix and tw spicules. Female with two ovaries and a tapering posterior end; vulv situate in the hinder half of the body. Embryos without teeth, and wit slightly developed œsophageal bulb.

Metastrongylus apri Gmelin 1789.

Synonyms.—*Gordius pulmonalis apri* Ebel 1777, *Ascaris apri* Gmelin 178 *Strongylus suis* Rudolphi 1809, *S. paradoxus* Mehlis 1831, *S. elongatus* Dujardi 1845, *S. longevaginatus* Diesing 1851.

Metastrongylus apri is not uncommonly found in the bronchial tubes of pig in Germany (60 per cent. Berlin, 15 to 52 per cent. Leipzig); occasionally i infects other animals, including man. *Filaria trachealis* Rainey 1855, found b Rainey and by Bristowe, may be infections of man with this parasite. Diesin recognized the worm in the lung of a boy aged six in Klausenberg in 184 It is said to also occur in the intestine, but this is looked upon as acci dental, as its usual habitat is the lung, where it may cause pneumonia and bronchitis.

Morphology.—Body relatively short; colour, white or brown; mouth with six lips, of which the two lateral are the largest. Male 12 to 25 millimetre in length, with bilobed bursa with five ribs in each lobe, and thin spicules about 4 millimetres in length. Female 20 to 40 millimetres in length, with a curved posterior end, close in front of which is the anus, while the vulva opens on a papilla just in front of this. Eggs elliptical, 50 to 100 μ by 39 to 72 μ. when oviposited, they already contain an embryo.

Life-History.—Only the embryonic and larval development appear to have been studied. From analogy with Agchylostoma a skin infection would be presumed nowadays, and, further, the fact that the worms have been noted in the alimentary canal bears quite a different significance to what it did years ago, as it may be natural for the worms at times to travel from the lungs to the bowel like the Agchylostome. It is interesting to note that Leuckar failed to infect sheep by feeding them with bronchial mucus full of embryos

Pathogenesis.—This subject has recently been studied by Santiocchi, and consists essentially of bronchitis, broncho-pneumonia, and pneumonia.

Trichostrongylus Looss 1905.

Body tapers gradually from the genital opening anteriorly. Head with three small lips and blunt or pointed papillæ, without cuticula protuberances or neck papillæ. Cuticle transversely striated œsophagus long. Male with the bursa closed round by large side flaps, without evident median folds; spicules spoon-like, with a boat-shaped accessory piece.

Female with the genital opening in the posterior half of the body Tail short, with two small papillæ near the tip. Egg thin-shelled

Three species: *Trichostrongylus instabilis*, *T. probolurus*, *T vitrinus*.

Trichostrongylus instabilis Railliet 1893.

Synonyms.—*Strongylus instabilis* Railliet 1893, *S. subtilis* Loos 1895.

This species was found by Looss in post-mortems on fellahs i Alexandria and Cairo, and also by Ijima in a woman in Japan. I man, however, it is only an accidental parasite, being really foun in the duodenum, rarely in the stomach, of sheep, antelopes, drome daries in Egypt, and monkeys in North America.

Morphology.—Male 4 to 5 millimetres in length, and 0·08 milli metre in thickness just in front of the bursa. Spicule 135 to 145 in length, and the accessory portion 70 μ in length, with a lon muscular œsophagus. Bursa with two lateral semicircular wing connected by a cross-bridge. Ribs arranged asymmetricall Female 5 to 6 millimetres in length, and about 0·09 millimetre i breadth. Posterior extremity tapers to a pointed tail, in front o which the anus is situated, 0·055 to 0·07 millimetre, and the vulv 1·05 to 1·2 millimetres. Eggs 72 to 80 μ by 40 to 43 μ; whe oviposited, generally contain eight to twelve celled embryo.

Life-History.—This is not known.

Pathogenesis.—Believed to be unimportant.

Trichostrongylus probolurus Railliet 1896.

Synonym.—*Strongylus probolurus* Railliet 1896.

This parasite lives in the duodenum of sheep, antelopes, an dromedaries in Egypt, and has also been found in man in Egypt.

Morphology.—Male 4·5 to 5·5 millimetres in length, 0·08 millimetre in breadth just in front of the bursa. Spicule 126 to 134 μ accessory piece 75 to 80 μ in length.

Female 4·5 to 6 millimetres in length, anus 0·04 to 0·05 millimetre, and vulva 1·08 to 1·25 millimetres in front of the tip of th tail, which is short.

Egg 76 to 80 μ by 43 to 46 μ.

Pathogenesis.—As *T. instabilis.*

Trichostrongylus vitrinus Looss 1905.

T. vitrinus is found in the duodenum of sheep and dromedaries and also in man in Egypt.

Male 4 to 5·5 millimetres in length by 0·085 millimetre in breadth in front of the bursa, which is larger than in the other two species Spicule 160 to 170 μ, accessory 85 to 95 μ in length.

Female 5 to 6·5 millimetres long; vulva 1·15 to 1·25 millimetres in front of the tip of the tail; egg 84 to 90 μ by 46 to 50 μ.

Life-History.—This is not known.

Pathogenesis.—Believed to be unimportant.

SUBFAMILY: SCLEROSTOMINÆ Railliet.

Strongylidæ with armed mouth and bursa copulatrix provided with ribs.

Genera.—*Agchylostoma, Necator, Triodontophorus, Œsophagostoma, Physaloptera.*

Agchylostoma Dubini 1843.

Synonyms.—*Ancylostoma* Dubini 1843, *Dochmius* Dujardin 1845 *pro parte.*

Sclerostominæ with the head end, where the mouth is situated, abruptly truncated. Mouth large, round, with its ventral margin armed with two pairs of strong hook-like teeth, the points of which are bent backwards, while the bases are continuous posteriorly with longitudinal riblike thickenings of the external surface of the capsule wall. The aperture of the dorsal œsophageal gland can be seen in the dorsal wall of the mouth capsule.

Male with a three-lobed bursa, broader than long, with two spicules. Female with vulva behind the middle of the body.

Agchylostoma duodenale Dubini 1843.

Synonyms.—*Strongylus quadridentatus* von Siebold 1851, *Dochmius anchylostomum* Molin 1860, *Sclerostoma duodenale* Cobbold, *Strongylus duodenale* Schneider 1866, *Dochmius duodenalis* Leuckart 1876 *pro parte.*

This worm, which is the great cause of tropical anæmia, was perhaps known to the ancient Egyptians under the term 'Heltu,' mentioned in the 'Ebers Papyrus,' which is supposed to have been written some 1550 years B.C., the disease being called A.A.A., and a remedy being advised. Perhaps the same anæmia is referred to in the 'Harita Samhita' under the term 'pandu roga,' which was said to be caused by swallowing clay. If this is correct, then knowledge of anæmia due to geophagy is very old indeed. If the ancients did really know about this worm, and the disease caused thereby, the knowledge was totally lost, and it was not till Dubini in 1838 discovered the worm in a peasant-woman in Milan that modern medicine knew anything about its existence. Pruner, in 1846, found the parasites in Egypt, and Griesinger, in 1851, showed that it was the cause of Egyptian anæmia. Wucherer, in 1872, found that it was the cause of tropical anæmia in Brazil (called 'opilaçao'). Perroncito found that it was the cause of the anæmia which badly affected the miners employed in the St. Gothard tunnel. Grassi and Parona in 1878 discovered the eggs in the fæces, thus enabling a diagnosis to be made during life. The wide geographical distribution of the parasite, and the amount of disease which it causes, is slowly being realized, and the deaths from anæmia, general dropsy, and so-called beri-beri, etc., in different tropical regions are being found to be due to this animal.

The development and method of infection have been completely traced out by Looss in Egypt in a most masterly manner.

In 1902 Stiles found that under the term *Agchylostoma* two different parasites were being confused, one corresponding to Dubini's *Agchylostoma duodenale*, and the other new, which he named *Necator americanus*. Leiper has shown how widespread this latter parasite is.

The geographical distribution is probably not correctly known, because in many places it is confounded with *Necator*. It is supposed to be cosmopolitan in tropical regions, and in mines and tunnels in colder climates, in which, of course, the air-temperature is higher than that of the outside.

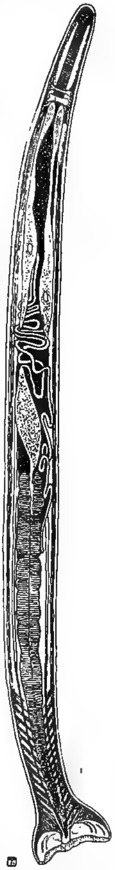

FIG. 168.—A
CHYLOSTOM
DUODENAL
DUBINI (MALE

(After Looss.

Morphology.—The body is cylindrical, tapering from back to front in both sexes. During life it is flesh-coloured. The cuticle is ringed. The mouth is terminal, with a chitinous wall, which ventrally carries two pairs of hook-like teeth, and dorsally one pair. Close t the base of the outer ventral tooth opens the single celled head glan which runs through nearly half the length of the body. In the flo of the mouth there are two ventral chitinous plates, and the prominent opening of the dorsal head gland (often called a tooth).

Male measures about 10 millimetres in length by 0·4 to 0·5 millimetre in breadth, and possesses a bursa copulatrix at the posterior end, which is umbrella-shaped and supported by chitinous rods, which are arranged as follows: In the median dorsal line is the costa dorsalis, which divides dorsally into two small branches, which are ramified at their tips. Postero-laterally there is one root on each side—the single costa dorsalis externa, in front of which is a single broad lateral root, which divides into the costa lateralis posterior, the costa lateralis media, and the costa lateralis externa; while anteriorly also on each side is the costa ventralis. Through the opening of this bursa project the two spicules, unless they are retracted, which are long and slender, and measure about 2 millimetres in length. The male generative apparatus consists of a testes in the form of a tube, an oval vesicula seminalis, and a long cement gland, whose secretion fixes the male to the female during conjugation, and a spicule sac.

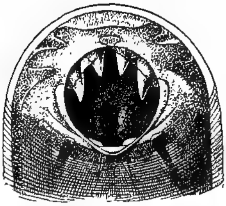
FIG. 169.—ANTERIOR END OF AGCHYLOSTOMA DUODENALE DUBINI.

(After Looss, from Mense's 'Tropenkrankheiten.')

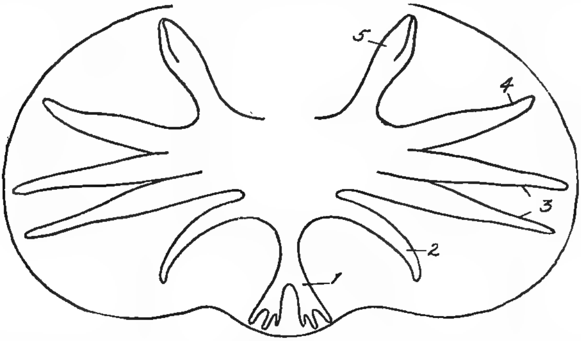

FIG. 170.—THE MEDIAN AND EXTERNAL CAUDAL BURSA OF AGCHYLOSTOMA DUODENALE DUBINI.

1, Costa dorsalis; 2, costa dorsalis externa; 3, costa lateralis posterior et externa; 4, costa lateralis media; 5, costa ventralis.

(After Railliet, from Stiles's Report.)

The female measures 12 to 13 millimetres in length, and has the vulva at the junction of the middle and hinder parts of the body, from which a short vagina opens into two tubes, which are divisible into ovijector, uterus, receptaculum seminis, and an ovary.

Life-History.—The adult worms live chiefly in the jejunum of the host, where they feed upon the villi. Blood is only accidentally found in a worm. Here the females lay the eggs, which are oval in form, with broad rounded poles, surrounded by a colourless shell, whic is really double, but looks single, inside which lies an oval granula mass separated from the shell by a considerable space. As the eg travels down the alimentary canal the granular mass divides into two, and finally into four segments, in which condition the egg is usually found in the fæces. Development proceeds in the fæces depending upon the temperature of the atmospheric air. In twenty-four hours, if supplied with air, water, and heat, the embryo can be seen coiled up in the egg, from which it escapes as a larva, and feeds on the fæcal material. The larva is needle-shaped, pointed posteriorly, and measure 200 to 250 μ in length by 15 to 17 μ in breadth, and is rhabdite in form, with a long cylindrical terminal mouth, opening into an œsophagus, which, after narrowing, swells out into a bulb with three valves. The straight intestine surrounded by granular material opens into an anus situate some distance in front of the tip of the tail. This larva undergoes a first ecdysis when it becomes narrower, and the œsophagus and mouth lose their characteristic appearance, while it forms a new skin inside the chitinous cuticle, so that (at the end of five days in the tropics) it now ceases to grow and feed, and takes to water or moist earth, where it can remain unchanged for months, living on the food-material enclosed in its own cells (stage of encystment). During this condition it may be quite active, and can swim and climb up any surface which is wet. This is an important factor in explaining the production of certain kinds of skin eruptions. It is now ready to infect man, which it does through the hair-follicles of the skin, causing eruptions or sores —*e.g.*, ground-itch.

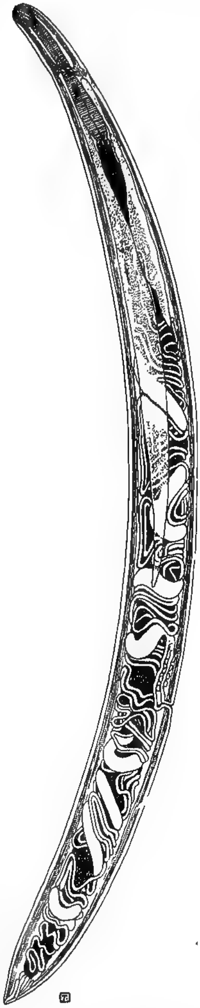

FIG. 171.—AGCHYLOSTOMA DUODENALE DUBINI (FEMALE). (After Looss.)

From the hair-follicles it forces its way via the subcutaneous tissue into the venous blood-vessels and lymphatics. In the former it reaches the right heart and the lungs easily; in the latter many are killed in the lymphatic glands, but some get through to the blood, and in this way are carried to the lungs. They now work their way out of the capillaries into the lumen of the air cells, and travel up the bronchi, trachea, and larynx into the œsophagus (they might by chance get into the mouth), and so through the stomach to the intestine. The time occupied by this journey is believec to be from seven to ten days. In the skin they undergo thei second ecdysis, and later a third and fourth ecdysis takes place ir the alimentary canal, the third in four to five days, and the fourtl from four to six days after their arrival. They now measure 3 to millimetres in length, and eight days later the generative organs begin to attain maturity, and the first copulations take place, anc a few days later the first eggs appear in the fæces, thus completing the cycle of development, of which the portion after infectior occupies four to six weeks.

The more important morphological changes which take place in the humar body may be briefly recapitulated.

On entering the skin the third stage of development begins, during whicl the provisional buccal capsule is formed. A third ecdysis ushers in the fourtl stage, characterized by the provisional buccal capsule armed with a dorsal and a ventral pair of teeth. During this stage the sexes become differentiated and the permanent buccal capsule is formed. The fourth ecdysis results ir the appearance of the adult worms.

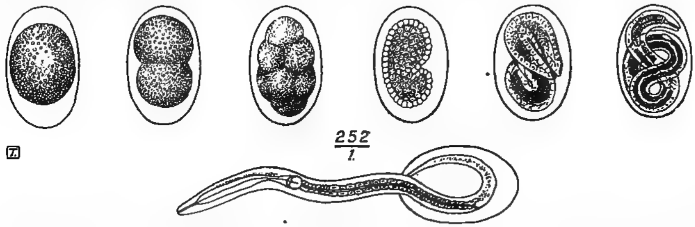

FIG. 172.—AGCHYLOSTOMA DUODENALE DUBINI: DEVELOPMENT OF THE RHABDITIFORM EMBRYO.

(After Looss, except the last figure, which is after Perroncito.)

The number of females can be calculated from the number o eggs in the fæces by the formula $X=\frac{A}{47}$, where X is the numbe of females and A the number of eggs in a gramme of fæces.

This history has been pieced together by Looss from observations on the infection of *Agchylostoma duodenale* in man and *A. caninum* in dogs.

These discoveries of Looss have been confirmed by Lambinet. Sambon while agreeing with the view that the worms penetrate the skin and worl their way to the lungs, considers that they pass from the pulmonary arter to the pulmonary veins, and in this way reach the general blood-stream, anc in due course the jejunum, the mucosa, of which they pierce, and enter th lumen of the bowel. He believes that the worms seen in the trachea, larynx and stomach by Looss are merely stray specimens which have escaped in th air cells from the vessels of the lungs. His reasons for this belief are:

1. The larval forms of *A. duodenale* have seldom been found in the stomach and when found in this organ are lodged beneath the epithelium.
2. They are invariably absent from the duodenum.
3. They have been found in the left heart, in the pulmonary and azygo veins, in the thoracic duct, in the peritoneum, in the kidneys, in the lympl glands, and in the connective tissue of various regions.
4. At the beginning of the infection there is always an intense hæmorrhagi

inflammation of the jejunum, which entirely subsides later on, notwithstanc ing the presence of enormous numbers of parasites in the intestine.

5. Immature forms have been found again and again in blood-filled spac beneath the intestinal mucosa by Bilharz, Griesinger, Sonsino, Grassi, an many other competent investigators.

6. A number of other worms which inhabit the intestinal cavity at maturit such as *Œsophagostomum*, *Sclerostomum*, *Ascaris*, *Gnathostomum*, etc., i an earlier developmental stage are usually found either free or encystec beneath the intestinal mucosa.

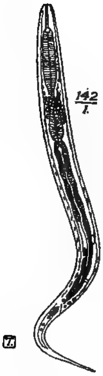

Fig. 173.

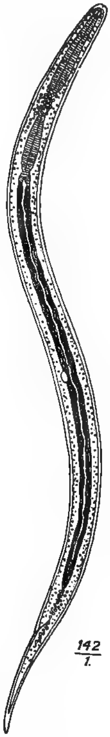

Fig. 174.

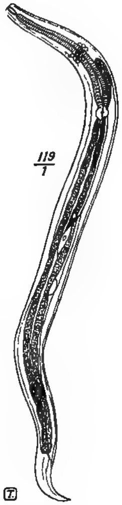

Fig. 175.

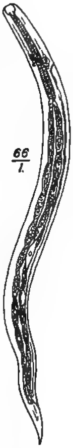

Fig. 176.

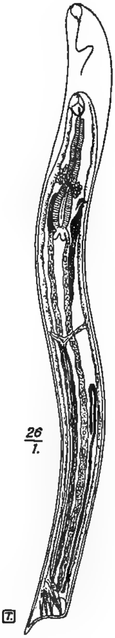

Fig. 177.

Fig. 173.—Agchylostoma duodenale Dubini: First (larval) Stage o Development. (After Looss, from Mense.)

Fig. 174.—Agchylostoma duodenale Dubini: Second Stage of Develop ment. (After Looss, from Mense.)

Fig. 175.—Agchylostoma duodenale Dubini: Third Stage of Develop ment. (After Looss, from Stiles.)

Fig. 176.—Agchylostoma duodenale Dubini: Fourth Stage of Develop ment. (After Looss, from Stiles.)

Fig. 177.—Agchylostoma duodenale Dubini: Fifth Stage of Develop ment. (After Looss, from Stiles.)

He also believes that when the larvæ are taken in by way of the mout they probably pierce through the walls of the œsophagus like the larvæ o *Hypoderma bovis* (see Chapter XX.), and reach their intestinal habitat by way o the vessels in exactly the same way as those which penetrate the hair-follicle.

Necator Stiles 1903.

Sclerostominæ closely resembling *Agchylostoma*, but distinguished therefrom by the small mouth capsule, which is armed only by semilunar plates. The head is strongly bent dorsally. In the male the bursa is bilobed. In the female the vulva lies in the anterior part of the body.

Species.—*Necator americanus.*

Necator americanus Stiles 1902.

Synonyms.—*Dochmius duodenalis* R. Leuckart *pro parte*, *Uncinaria americana* Stiles 1902, *Ancylostoma americanum* von Linstow 1903 *pro parte.*

In 1902 Stiles discovered that two distinct genera were being confused under the term *Agchylostoma*, and eventually called the new genus *Necator*. Leiper has recently shown that this new genu is very widely distributed over the world, and is the common caus of agchylostomiasis in Ceylon; while it occurs in India, Assam Burmah, the Philippine Islands, America, and has been found in West and Central Africa and in North-West Rhodesia. In du course, no doubt, it will be reported in other places.

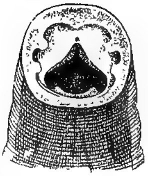

FIG. 178. — THE OVAL CAPSULE OF NECATOR AMERICANUS STILES.

(After Looss, from Mense.)

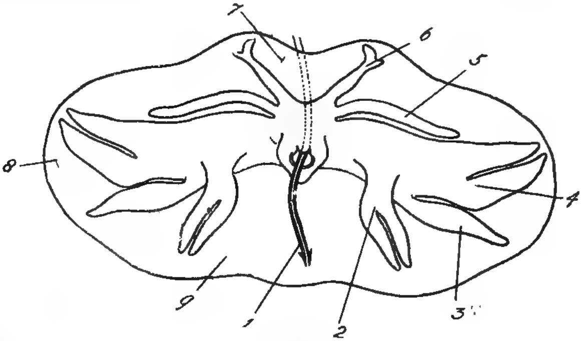

FIG. 179.—THE BURSA COPULATRIX OF A MALE NECATOR AMERICANUS STILES.

1, Spicules; 2, costa ventralis; 3, costa lateralis pos terior; 4, costa lateralis externa et costa lateralis media 5, costa dorsalis externa; 6, costa dorsalis; 7, dorsa lobe; 8, lateral lobe; 9, ventral lobe.

(After Stiles.)

Morphology.—The body is cylindrical, and somewhat attenuated anteriorly. Head acutely bent dorsally. Mouth with a ventra pair of prominent semilunar chitinous plates and a dorsal pair o slightly developed plates. Into the floor of the mouth projects th opening of the dorsal head gland, which appears like a dorsal conica tooth, while deep in the cavity appear one pair of dorsal and on pair of ventral submedian lancets. Excretory pore 0·5 millimet behind the mouth, with cervical papillæ on either side.

Male 7 to 9 millimetres in length and 0·3 to 0·35 millimetre i breadth. The bursa consists of two large lateral lobes joined to dorsal median lobe, which appears as if divided into two, and t an indistinct ventral lobe. There is a slight ventral enlargemen just posterior to the point at which the bursa joins the body-wal The costa dorsalis is divided at its base into two diverging branche which are bipartite. The common base of the costa dorsalis an costa dorsalis externa is very short, while the latter ray is long slender, and clavate. The costa lateralis externa is closely joine to the costa lateralis media. Two small precaudal papillæ can b seen anterior to the ventral rays. The spicules are long and slende 0·92 millimetre in length, and terminate in barbed points.

Female is 9 to 12·6 millimetres in length; vulva in the anterio half of the body, but near the equator. Eggs 57·5 to 80 μ by 3 to 52·5 μ; average, 66 by 40 μ.

Life-History.—Not known.

Pathogenesis.—It causes agchylostomiasis in certain regions.

Triodontophorus Looss 1901.

Synonyms.—*Triodontus* Looss 1901, *nec* Westwood 1845.

Sclerostominæ with small, almost spherical, thick-walled ora cavity, arising from the floor of which three teeth are found, eac of which consists of two surfaces joined together at an acute angle Male bursa is finely serrated at the edge. The female genital orific is situate a short distance in front of the tip of the tail.

Found in horses and men.

Triodontophorus deminutus Railliet and Henry 1905.

Railliet and Henry in 1905 discovered that a male and femal parasite presented in 1865 by Monestier to the Paris Natura History Museum, and collected post-mortem from an American negro who died in Mayotte, were not agchylostomes, but belonged to Looss's genus *Triodontophorus*. They named them *deminutus*, because of their small size. Leiper also met with some specimens of the same species from Johannesburg.

Morphology.—To the naked eye their size and general appearance resemble those of agchylostomes. The body is white, cylindrical, tapering towards the end. Cuticle transversely striated, and forms an over-hanging transverse fold across the ventral surface of the body at the level of the excretory pore.

The mouth-collar is moderately developed, with a depth of 0·04 millimetre. The anterior surface carries four small knob-like submedian papillæ, and the edge surrounds the entrance to the mouth with a double series of delicate fringes composed of cuticle. These two rows constitute the external and internal crowns of the corona radiata.

The buccal capsule is a barrel-shaped chitinous structure, capped and covered in by the mouth-collar and the corona radiata. Posteriorly it touches the dilated end of the œsophagus, whose chitinous lining expands into a funnel, uniting with the cuticle on the outside of the œsophagus, and coming near the cuticle of the buccal cavity. It shows three cuticular edges projecting into the lumen, which are continued forwards as three stout chitinous prongs or teeth, one dorsal and two ventral. The characters of these teeth are specifically important. They are formed of two plates curved longitudinally, and meet to form a keel. The œsophagus is muscular, 0·8 millimetre long, and with three fleshy valves guarding its entrance into the chyle intestine. The rectum is short, and ends in the anus, which is 0·24 millimetre from the tip of the tail. The excretory system opens on the ventral surface halfway between the posterior limit of the buccal cavity and the nerve ring.

The male is 9·5 millimetres long by 0·56 millimetre in breadth, with a spicule 0·9 millimetre long. Female is 14 to 16 millimetres in length, and 0·73 millimetre in breadth, with a tapering posterior extremity. The vulva is nearly 0·48 millimetre from the hinder end. The vagina is short, and opens into two uterine tubules. The uterine eggs are 60 to 80 μ by 40 μ, with a delicate shell and often a morula.

Life-History and Pathogenesis.—Unknown.

Œsophagostoma Molin 1860.

Sclerostominæ in which the mouth is small and circular, with a chitinous ring, which carries a fold and six papillæ. There is a marked swelling just behind the anterior extremity. Male bursa with two equal spicules; female with two ovaries, and the vulva opening situate near the anus.

Œsophagostoma brumpti Railliet and Henry 1905.

This worm was found in cyst-like nodules in the cæcum and colon of a negro on the Omo River, near Rudolph's Sea in East Africa. Only the female is known.

Morphology.—Female 8·5 to 10·2 millimetres long by 0·295 to 0·325 millimetre broad, white and cylindrical, tapering towards the posterior end. Cuticle transversely striated. There is a distension behind the oral cavity, which is formed of a cuticular band with a crown with twelve spines; on the front and inner side lamellæ; six head papillæ (two lateral, four submedian). Posterior end rounded off with three broad undulations.

Pathogenesis.—Not known.

Physaloptera Rudolphi 1819.

Sclerostominæ possessing mouth with usually two lips, each with papillæ and teeth. Posterior end of the male lancet-shaped, owing to a widening of the cuticle. Bursa bladder-shaped, with four pairs of pedunculated external papillæ and a number of sessile internal papillæ and unequal spicules. Female with two ovaries; vulva situated anteriorly.

Physaloptera caucasica von Linstow 1902.

This has only been found once by Ménétriés in the alimentary canal o man in the Caucasus.

Male 1·42 millimetres long by 0·71 millimetre broad. Female 27 millimetres long by 1·14 millimetres broad. Eggs 57 by 39 μ.

Physaloptera mordens Leiper 1907.

Leiper recently gave notice that he had found a *Physaloptera* in a native of Uganda at Entebbe, which differed from *P. caucasica* not only in size, but in the characters of the caudal extremity of the male.

FAMILY 9. ASCARIDÆ.

Nemathelminthes with three oral papillæ, one dorsal and tw ventral; œsophagus with a bulb. Male with one or two spicules female with two ovaries.

Genera.—*Ascaris, Toxascaris, Belascaris, Oxyuris.*

Ascaris Linnæus 1758.

Ascaridæ in which the oral cavity is surrounded by three larg papillæ, one placed dorsally and two ventrally. Male with tw equal spicules and numerous pre-anal and post-anal papillæ. Vulv in front of the middle of the body.

Species.—*Ascaris lumbricoides, A. texana, A. maritima.*

Ascaris lumbricoides Linnæus 1758.

This is one of the most common parasites in the tropics. It is however, possible that other species escape recognition by bein casually considered to be *Ascaris lumbricoides*. It is usually me with in the small bowel, but may be found post-mortem in th stomach, œsophagus, mouth, nose, larynx, trachea, or bronchi. I may also be found escaping from the anus. More rarely it has bee seen in the liver, causing abscesses, in the pancreatic duct, and i the vermiform appendix, and in worm abscesses in the body-wall Usually it gives rise to no symptoms, but at times, when in larg numbers, it may cause pathological effects.

Morphology.—It is yellowish in colour, with often a faint trac of a reddish tinge. In form it is spindle-shaped. Male is 15 t 25 centimetres in length and 3 millimetres in diameter. The posterior extremity is conical, and bent ventrally, with two spicule 2 millimetres in length, and broader at the tips. On each side o the cloaca there are seventy to seventy-five papillæ, of which seve pairs are post-anal. Female is 20 to 40 centimetres in length b 5 millimetres in breadth. The vulva is at the junction of th anterior and middle thirds of the body.

Life-History.—The eggs are laid in the small intestine, and appea unsegmented in the fæces. They measure 50 to 70 μ in length b 40 to 50 μ in breadth, surrounded by a thick transparent shell which has an externally irregular coating of albumin, which i stained brownish-yellow by the stercobilin of the fæces. Thes eggs can stand alteration in temperature and moisture. In warm moist earth the embryo appears in about a month in the form of spiral roll, but does not hatch until it reaches the interior of man as was shown by the experiments of Davaine, Grassi, Calandruccio Lütz, and Epstein, when it hatches and develops into an adult.

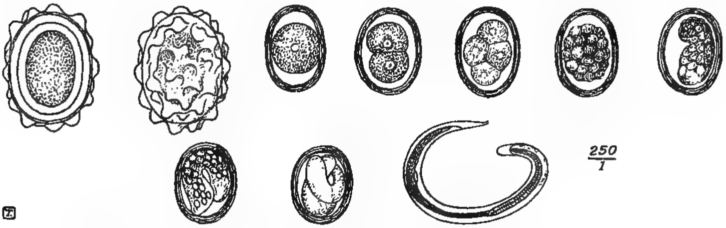

FIG. 180.—DEVELOPMENT OF ASCARIS LUMBRICOIDES.
(After Stiles.)

Leuckart and von Linstow had believed that an intermediate host was necessary, but this appears from the above experiments to be erroneous.

The eggs infect human beings through polluted vegetables, fruits, water, or hands soiled with dirt.

Stiles found that the house-fly could carry the egg, which passed through its alimentary canal unaltered. The worm matures, and deposits ova in one month from entering the body.

Pathogenesis.—It is only pathogenic in large numbers, or when it invades the liver, causing abscess, or the appendix, causing appendicitis.

Ascaris (?) **maritima** Leuckart 1876.

An immature worm, possibly accidentally swallowed in food, was vomited by a child in North Greenland in 1865, and was supposed to be an immature female *Ascaris.*

Ascaris (?) **texana** Smith and Goeth 1904.

Stiles appears very doubtful as to whether this worm is an *Ascaris.* The female only is known, measuring 58 to 60 millimetre in length. Uterine eggs 60 by 40 μ. It was found in a man in Texas.

Toxascaris Leiper 1907.

Ascaridæ with the anterior end of the body bent dorsally, cuticle finely striated, œsophagus simple, without a bulbous portion. Palpi of lips club-shaped. Male with a tapering, acicular tail, an without ventral protuberance behind anus. Six pairs of post-ana papillæ in two groups, the ventral pairs continuous, with a pre-ana row on each side of the body, and three lateral pairs on the oute aspect of the tail. Testis lies in the anterior part of the posterio half of the body. Seminal vesicle long and tubular. Ejaculator duct short. Female with vulva about the centre of the body Egg oval and smooth.

Of the species belonging to this genus, only one, *Toxascaris cani* Werner 1782, is known in man.

Toxascaris canis Werner 1782.

Synonyms.—*Lumbricus canis* Werner 1782, *Ascaris canis* Gmeli 1789, *A. marginata* Rudolphi 1802.

Toxascaris canis is the common *Ascaris* of dogs, which used t be called *A. canis*, but recently Leiper, when examining a numbe of specimens of *A. lumbricoides* in Egypt, found among them severa smaller and apparently young forms. On examining these, h found that they had winged expansions on either side of the head which indicated that they were not *A. lumbricoides*. On furthe examination they proved to be the same species as that found i dogs, but differed from that found in cats. Up to that time *A. cani* in the dog and *A. mystax* in the cat were supposed to be identical Finally, on careful anatomical examination, it was found that th two not merely differed considerably from one another, but als from *A. lumbricoides*. He therefore formed two new genera—*Toxascaris* and *Belascaris*. *Toxascaris* has only been recorded onc so far in man.

Morphology.—Body white or reddish, head curved dorsally, wit two membranous lateral expansions, broader behind than in front Male 5 to 10 centimetres in length, with curved tail, possessing tw small lateral membranous wings and twenty-six papillæ. Femal 9 to 12 centimetres in length, with an obtuse tail. Eggs 75 to 80 in diameter.

Life-History.—Development is believed to be direct.

Pathogenesis.—It often causes intestinal and nerve symptoms i dogs. Post-mortem the mucosa of the intestine is tumefied an catarrhal.

Belascaris Leiper 1907.

Ascaridæ with the anterior end of the body bent ventrally, cuticl coarsely striated, œsophagus with a distinct bulbous portion. Mal with a probular tail—*i.e.*, like a closed fist, with forefinger semi-extended. Immediately behind the anus there is a protuberance with a pair of papillæ. On the tail there are two ventral and tw lateral pairs of papillæ, the tips of which support a slight expansio of the cuticle. The testis is situate in the anterior half of the body The vesicula seminalis is remarkably long, and there is a shor ejaculatory duct. Female with vulva situated in the anterior par of the body. Egg with a corrugated shell.

Type.—*Belascaris mystax* Zeder 1800.

Belascaris mystax Zeder 1800.

Synonyms.—*Fusaria mystax* Zeder 1800, *Ascaris alata* Bellingham 1839.

This *Ascaris* is found in cats, and has been recorded nine times in man.

Morphology.—Head curved ventrally, with two membranous lateral expansions. Male 4 to 6 centimetres in length; female 4 to 10 centimetres in length.

Pathogenesis.—It rarely causes any symptoms.

Oxyuris Rudolphi 1803.

Nematoda in which the three labial papillæ are not very distinct. Œsophagus long, with a distinct dilatation. Male with curved posterior end, one spicule, and two pairs of preanal papillæ. Female with straight posterior end, which tapers to a point. Vulva in the anterior end of the body.

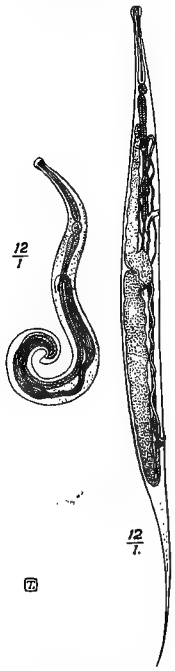

FIG. 181.—OXYURIS VERMICULARIS.
The male is to the left, the female to the right.
(After Claus.)

Type.—*Oxyuris vermicularis.*

Oxyuris vermicularis Linnæus 1767.

Synonyms.—*Ascaris vermicularis* Linnæus 1767, *Fusaria vermicularis* Zeder 1803.

Oxyuris vermicularis is the pin or thread worm, and occurs, as far as is known, only in man and all over the world. It is believed to live in the lower part of the small intestine at first, and then the gravid females travel to the large bowel. It has been known from the earliest times.

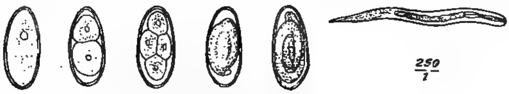

FIG. 182.—DEVELOPMENT OF OXYURIS VERMICULARIS.
(After Leuckart, from Stiles.)

Morphology.—It is a minute white round worm, with transversally striated cuticle, which forms two ridges along the ventral and dorsal surfaces corresponding to the lateral ridges.

Male is 3 to 5 millimetres in length, with a spirally rolled posterior extremity, with one spicule and six papillæ. Female is 10 millimetres in length and 0·6 millimetre in breadth, with a long pointed tail.

Life-History.—The egg, when deposited from the uterus, measures 50 to 52 μ by 16 to 24 μ, with a thin shell and a fairly well-developed embryo. The dorsal surface of the egg is more convex than the ventral. These eggs escape in the fæces. They are then reintroduced into the mouth or nose by self-infection, fruits, vegetables etc., hatch, and grow in the small intestine into males and females

After fertilization the males die off and the females travel int the cæcum, and later into the colon, and have a great tendency t wander through the anus to the outside. The duration of life o *O. vermicularis* in the human body is not known.

Pathogenesis.—In large numbers may set up enterocolitis ; i small numbers it causes only irritation.

Order 2. GORDIACEA.

Nemathelminthes with the intestinal canal always atrophied anterior in the adult ; head without papillæ ; two testes, but never spicules in th male ; vulva always united with the posterior portion of the intestine t form a cloaca ; rare in man ; only accidental parasites.

These worms are popularly known as horsehairs, and are supposed t cause serious and even fatal disease in man or animals if swallowed. Thei pathogenesis has recently been studied by Stiles, who is unable to suppor the popular belief as to the serious nature of these parasites in man. The are very long, thin worms, like *Filaria*, which can be found in ditch-wate swimming freely or twining round water-plants.

The body is covered with a well-developed, two-layered cuticle. Th mouth and the anterior part of the intestine is obliterated. The posterior en of the male is lobed, and without spicules. In the female there are two ovarie and the egg-sacs, which open by means of oviducts into a uterus. The male are often blackish brown, and the females light clay brown.

The life-history of *Parachordodes tolosanus* is very complicated : the firs larva enters the larva of the alder-fly (*Sialis lutaria* L.), in which it live during the winter, and passes over to the imago of the same insect, which i eaten by a beetle (*Pterostichus niger*), in which the first larva changes becoming a second larva, which lives in the beetle during the second winte and finally escapes into the water about twenty months after hatching. I the water it soon becomes adult.

The Gordiacæ includes the family Gordiidæ, which is divided by Cameran into four genera : *Gordius*, *Paragordius*, *Parachordodes*, *Chordodes*.

Without going into details, it may be said that the following species hav been reported as parasitic in man :

Gordius aquaticus L. 1758.—Four recorded cases in Europe with abdomina symptoms, pain, vomiting, etc., and nervous symptoms, hysteria, and neuralgia

G. chiliensis E. Blanchard 1849.—This is simply based on the legends o Chilian Indians, who fear the worm.

Paragordius varius Leidy 1851.—Four cases of infection in North America Worms were expelled *per anum* or by vomiting. Symptoms: unimportant.

P. tricuspidatus Dufour 1828.—One case in France. Symptoms: sligh colic. Worm extracted from the throat.

P. cinctus von Linstow 1906.—From a man in Leydenburg, in the Transvaal

Parachordodes tolosanus Dujardin 1842.—Four cases, in one of which i is accused of causing epileptiform fits. Cases occurred in France and Italy.

P. pustulosus Baird 1853.—One case in Italy caused anal pruritus an discharge.

P. violaceus Baird 1853.—One case in France; it lodged in the throa before expulsion.

P. alpestris Villot 1884.—One case in France.

Undetermined.—Ward, in 1903, published the account of a case in which th genus of the worm was not determined.

CLASS II.

Order 3. ACANTHOCEPHALA Rudolphi.

Nemathelminthes with a retractile proboscis armed with several rows of spines or hooks ; intestine absent ; parasitic in the intestine of vertebrates.

The Acanthocephala are elongated cylindrical worms, in which the body can be divided into proboscis, neck, and trunk. The proboscis is a hollow, finger-shaped, retractile process, covered with a thin cuticle, and armed with rings of hooks arranged in longitudinal rows. The neck is not always discernible. The trunk has a rounded posterior end, and consists of a body-wall with muscular layers, covered by a thin cuticle, enclosing the excretory and reproductive organs. The sexes are separate. The male organs are two oval testes, whose vasa efferentia unite into a vas deferens, which opens into a cirrus contained in a pouch or bursa, and provided with a prostate gland.

The female organs consist of two ovaries, which break down into masses of cells which escape into the cœlom. Here the ova are fertilized and the embryo is formed, and escapes through a funnel-shaped structure called 'the bell' into the uterus, and so through the vagina and the genital orifice at the posterior end of the body into the lumen of the host's intestine.

The embryo leaves the host with the fæces, and, getting into water, enters the alimentary canal of a crustacean, water-insect, or fish, inside which it hatches. It now bores its way through the intestinal wall into the cœlom, where it develops all its organs except the reproductive.

The crustacean, water-insect, or fish, must now be eaten by a vertebrate, when the acanthocephalid becomes sexually mature in the intestine. They are very rarely found in man.

Classification.—The Acanthocephala are divided into four families by Hamann and Shipley : Echinorhynchidæ, Gigantorhynchidæ, Neorhynchidæ, Arhynchidæ. Human parasites, which are very rare, are only found in the first two families.

ECHINORHYNCHIDÆ.

Acanthocephala with elongated, smooth body ; proboscis can be retracted into a sheath with double walls.

Genus.—*Echinorhynchus.*

Echinorhynchus hominis Lambl 1859.

This parasite was found in the intestine of a boy who died of leukæmia ; it was 5·6 millimetres long. There appears to be much doubt as to whether this really was an *Echinorhynchus.*

Gigantorhynchus.

Large Acanthocephala with ringed, flat, tæniform bodies.

Gigantorhynchus gigas Goeze 1782.

This parasite was alleged by Lindemann to occur in man in South Russia, where Schneider says Melolantha is eaten raw. It is 10 to 15 centimetres long ; eggs 80 to 100 μ long, with three shells. Its usual life-history is that the adult is found in pigs, and the larva in Melolantha, Cetonia, Aurata, or *Lachnosterna arenata.*

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ACANTHOCEPHALA.

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CHAPTER XVII

BIOLOGICAL CAUSES OF DISEASE (*continued*) —ANNULATA AND ARTHROPODA

Annulata—Hirudinea—Arthropoda—Diplopoda—Arachnida—Crustacea—Chilopoda—References.

PHYLUM: ANNULATA.

METAZOA with elongated bodies divided externally into a number of rings which represent a division of the internal parts into segments or somites (metameres), usually with an extensive cœlom. Nervous system consists of a cerebral ganglion, with double commissure and ventral nerve cord. Organs of excretion in the form of metamerically arranged pairs of nephridia.

The only class of this phylum which contains animals of importance in tropical medicine is the Hirudinea or Discophora—*i.e.*, the leeches.

CLASS: HIRUDINEA.

Annulata with oval bodies, showing a dorso-ventral flattening and two suckers, one at each end.

Leeches are of interest in the tropics, firstly, because they may be a considerable nuisance as ectoparasites—*e.g.*, land leeches or *Hæmodipsa*; and, secondly, they may be of considerable danger to the health and even the life of a person as endoparasites—*e.g.*, the water leeches, particularly *Limnatis.*

As ectoparasites they are apt to fasten on the legs of persons going through grass or jungle. In fact, in Ceylon, while standing on a piece of grass in certain parts of the low country, the leeches can be watched converging from all quarters of the compass towards the observer.

Very often the bite is not noticed, and the leech or leeches may have sucked a considerable amount of blood before any attention is paid to them, and tales are told of persons feeling faint before noticing that they were being attacked by these creatures.

They are apt to get into the nose, naso-pharynx, or larynx with drinking water, and in this endoparasitic condition they may suck blood and cause epistaxis or hæmoptysis, and this may go on to such an extent that anæmia and even death may result.

It is hardly possible to believe that they can live in the stomach, for it is much more likely that they are at once killed by the gastric juice and digested.

A great many tropical countries appear to be plagued with leeches which affect men and animals as indicated above, but it is probable that Algeria, Palestine, and Ceylon are the most infested. Among the other places in which they are troublesome may be mentioned the Philippines, Java, Sumatra, Australia, Japan, and Chili. In Algeria and Palestine the leech lives in the pools of drinking-water, and here the endoparasitic form may be met with; whereas in Ceylon it is usually a land leech which attacks the individual, and therefore the ectoparasitic condition is common, while the endoparasitic is more rare, being due to *Hirudo multistriata*.

Morphology.—Leeches have an elongated, more or less oval, body, which is very retractile and extensile, and is marked by annuli or rings, of which several—usually five—form a somite. The number of rings to a somite is, however, reduced anteriorly and posteriorly, being abbreviated. At the anterior extremity is the oral sucker, and at the posterior the acetabulum. The skin possesses many unicellular dermal glands. The mouth-opening is situate in the anterior sucker, and the anus either in or just in front of the constriction which separates the posterior sucker from the body.

The male genital opening is placed on the twenty-fourth annulus, and the female five annuli behind it in *H. medicinalis*; but the female orifice may vary with regard to the male in other genera. A number of nephridial orifices can be seen as paired openings on the posterior annuli of many of the somites. Eyes exist as small, dark dots on the dorsum of the body, behind the anterior sucker. The mouth may be armed or unarmed. In the former condition it possesses three jaws—one dorsal and two ventro-lateral—each with a thickened free edge notched with teeth. In the latter there may be only a proboscis. Into the mouth open the salivary glands, which secrete a fluid which prevents the coagulation of the blood. The pharynx is an oval sac, with strong muscular walls and radial muscles, which can alternately contract and dilate the cavity, thus forming a sucking-pump. From the pharynx an œsophagus leads to the crop, which is a straight, thin-walled tube, with lateral diverticula.

Behind the crop comes the small stomach, which opens into a narrow straight tube—the intestine—which runs to the anus. The cœlom consists of a series of tubes containing red blood. The excretory system consists of the nephridia. There is a supra-œsophageal ganglion, a nerve collar, and a ventral nerve chain. The male reproductive organs are a number of testes, with vasa efferentia opening into two vasa deferentia, which, after coiling into epididymes, run to the single penis. The female organs are a pair of ovaries and oviducts opening into a single vagina.

Biology.—Leeches appear to be essentially water animals, and though certain genera can live on land, still, they require a great deal of moisture. Hence land leeches retire into moist places under stones, earth, etc., and only come out when requiring food. In dry weather not a leech can be seen, while in damp weather they may be very abundant.

Any disturbance of the air appears to affect them. Hence they are quickly aroused from their retreats when a human being or animal approaches, and set forth at once, often with considerable speed, to the attack.

The bite is not always painful at first, and may not be noted until the flow of blood is observed. The leech, while biting, keeps itself and the skin of the victim moist by liquid excreted by the nephridia and the dermal glands. When it has gorged itself with blood it drops off, but its salivary secretion prevents the coagulation of the blood, and hence the site of the leech-bite bleeds considerably for some time. The blood is stored up in the crop and its cæcal diverticula, and only a little is used day by day for food.

Pathogenesis.—Leeches are hosts of trypanosomes and other parasites, and their bite may possibly introduce these parasites into the skin of the human victim as well as into that of animals.

The marked feature of the pathogenesis is loss of blood, not merely caused by the sucking of the leech, but also by the bleeding from the wound caused by the bite. Further, the punctures caused by *Hæmadipsa ceylonica* are extremely liable to become ulcers, which, according to Marshall and Davy, caused a high rate of mortality among the Madras sepoys and coolies during the Kandyan rebellion of 1818 in Ceylon. Short of death, amputation of the limb was necessary in those days. We are not inclined to consider these old statements as erroneous, because it is quite possible that some organism is often introduced into the affected part by the leech-bite. For a further discussion of the pathogenesis, see the chapters on Diseases of the Respiratory Organs and of the Skin.

Classification.—The class Hirudinea may be divided into several orders :—

Order I. *Rhynchobdellida.*—Hirudinea without jaws, with an extensile proboscis and with colourless blood.

The Rhyncobdellida are divided into two families :

Family 1. *Ichthyobdellidæ.*—Rhynchobdellida with the anterior narrower part of the body distinct from the posterior, and with both suckers distinct from the body.

To this family belong the genera *Pisciola* Blainville 1818 and *Pontobdella* Leach 1815, mentioned in the chapter on Protozoa.

Family 2. *Glossiphoniidæ.*—Rhynchobdella with the anterior sucker fused to the body, while the posterior is distinct.

Among the genera of this family is *Hæmentaria* de Filippi 1849, of which *H. officinalis* de Filippi is found in Mexico, and is alleged to cause drowsiness, buzzing in the ears, and a painful rash, when it bites a person. The causation of these symptoms is obscure. Another species is *H. ghilianii* de Filippi 1849.

Other genera are *Glossiphonia* Johnson 1816, *Hemiclepsis* Vejdovsky 1883, and *Placobdella* R. Blanchard 1893.

Order II. *Arhynchobdellida.* — Hirudinea usually with jaws, without a proboscis, and with red blood, with two families, Gnathobdellidæ and Herpobdellidæ, of which only the first concerns us.

The Gnathobdellidæ are classified into the following subfamilies : Hirudininæ and Hæmadipsinæ.

HIRUDININÆ R. Blanchard.

Aquatic Gnathobdellidæ, with ten eyes, and with an eyeless ring between the third and fourth pairs of eyes.

In this family come the following genera : *Hirudo*, *Limnatis*, *Hæmopis*, *Hirudinaria*, *Limnobdella*, *Macrobdella*, and *Whitmania*.

Hirudo Linnæus 1746.

Hirudininæ with twenty-six somites, of which the 1st and 2nd have each one ring; 3rd, two rings; 4th, 5th, and 6th, each three rings; 7th to 22nd, each five rings; 23rd, three rings; 24th, 25th, and 26th, each two rings; making in all 102 rings.

Eyes are carried on the 1st, 2nd, 3rd, 5th, and 8th rings. The buccals are the 5th and 6th, and the post-buccals the 7th and 8th. The first pair of nephridia is on the 13th, and the last (the 17th) pair on the 93rd ring.

The male orifice is between the 30th and 31st rings, which are the 2nd and 3rd of the 10th somite.

The female orifice is five rings behind that of the male—*i.e.*, between the 35th and 36th rings. The anus is situate on the 102nd ring, or between the 101st and 102nd.

Hirudo medicinalis Linnæus 1746 is found principally in Hungary. Var. *officinalis*.

H. troctina Johnston 1816 is the medicinal leech of England, France, Spain, and Algeria.

H. nipponia Whitman 1886. Japan.
H. sinica Blainville 1827. China.
H. quinquestriata Schmarda. Australia.
H. saigonensis. Cochin China.
H. asiatica R. Blanchard. Afghanistan and Persia.
H. timorensis R. Blanchard. Timor.
H. septemstriata Grube. South Africa.
H. hildebrandti R. Blanchard. East Africa, Victoria Nyanza.
H. multistriata Schmarda. Ceylon.

FIG. 183.—HIRUDO MULTISTRIATA SCHMARDA.
The common water leech of Ceylon.

Hæmopis Savigny 1817.

Synonym.—*Aulastoma* Moq. Tand. 1826.

Hirudininæ with 3 rings on the 23rd somite, and two rings to the 24th, 25th, and 26th somites. *H. sanguisuga* Beymann 1757 found in Europe, and *H. lacustre* Leidy in America.

Limnatis Moquin-Tandon 1826.

Hirudininæ, with a longitudinal groove on the inner surface of the upper lip of the anterior sucker. Jaws with more than 100 teeth.

Limnatis nilotica Savigny 1820. This leech is 8 to 10 centimetres in length, and is common in North Africa, the Canaries, South Europe, and Asia Minor, while it, or some other species, is found on the West Coast of Africa.

Limnatis mysomelas Serulias and Virey 1829 is found in Senegambia, and *L. granulosa* Savigny 1820 in India.

These leeches are of importance, because they are apt to get into the nose, naso-pharynx, pharynx, and larynx of persons drinking at pools of water, and to cause serious symptoms. Other species are *L. africana* R. Blanchard in Senegal and the Congo, *L. maculosa* Grube 1859 Singapore.

Hirudinaria Whitman 1886.

Hirudininæ with the sexual pores separated by several rings. Acetabulum very large.

H. javanica Wahlberg 1855. In Batavia, Sumatra, and Burma.

Limnobdella R. Blanchard.

Hirudininæ with 103 to 104 rings. Jaws without papillæ. The 6th somite with three rings, the 23rd with five rings.

L. grandis R. Blanchard. Timor, Sumatra, and Ceylon.
L. australis Besisto 1859. Sydney and New South Wales.
L. mexicana R. Blanchard. Mexico.

Macrobdella Verrill 1872.

Hirudininæ, jaws without sensory papillæ; teeth not numerous: 103 body-rings. Both genital openings on the 11th somite.

M. sestertia Whitman 1886. America.

Whitmania R. Blanchard 1884.

Hirudininæ with 105 to 107 rings; 6th segment with five rings; 23rd has always more than three rings. Teeth more or less rudimentary.

W. ferox R. Blanchard 1896. London Zoological Gardens and in Asia.

HÆMADIPSINÆ R. Blanchard.

Gnathobdellidæ, living on land, with ten eyes, and no eyeless ring between the 3rd and 4th eyes. The three last body somites (twenty-three to twenty-six) with only one ring each.

Genera.—1. *Hæmadipsa* Tennent 1861.

Synonyms.—*Hæmopis* Schmarda 1861, *Chthonobdella* Grube 1865.

Hæmadipsinæ, terrestrial in habit, 2 to 3 centimetres in length; subcylindrical, tapering slightly forwards, cephalic lobe, rounded when at rest, but pointed in extension; acetabulum moderately large, round, or oval, centrally attached, separated from the body only by a feeble constriction.

Eyes in five pairs, the rings bearing the 3rd and 4th pair, not separated by an intervening ring, the rings bearing the 4th and 5th pairs, separated by two rings. Œsophagus with three plications—one dorsal and two latero-ventral. The three maxillæ covered with teeth, which increase in size towards the converging anterior ends of the jaws. Clitellum includes three somites and fifteen rings. Genital orifices separated by five rings; nephridial pores at the margin of the body, the last pair opening in the constriction between the body and the acetabulum.

The land-leeches of Ceylon were separated from the genus *Hirudo* by Tennent in 1861, under the name of *Hæmadipsa* , and those of Australia by Whitman in 1886 under the term *Geobdella*, altered to *Moquinia* by Blanchard.

Land leeches are mostly tropical, living in the area defined by the parallels 40° N. and 40° S. of the Equator, for they appear to prefer a warm, moist climate. In the Himalayas they ascend to a height of 11,000 feet; but in Ceylon they diminish in numbers above 4,000 feet. They are to be found n Ceylon, India, Java, Sumatra, Luzon, Mindanao, Pelew Islands, Japan, New Guinea, Celebes, New South Wales, Queensland, and the southern provinces of Chili and Trinidad. They live under damp leaves and loose rubbish, and appear when the air is disturbed by the approach of man or beast, and so quickly do they rush to the attack that they have earned the name of the 'jumping leech.' As a rule they bite gently, but make a deep wound, the scar of which may take months to disappear. They fill themselves with blood in about thirty minutes, and then drop off.

H. zeylanica Blainville 1827. Ceylon.
H. umbata Grube. Sydney.
H. fallax R. Blanchard. Madagascar.
H. morsitans R. Blanchard. ,,
H. vagans R. Blanchard. Madagascar.
H. javanica Wahlberg. Java.
H. talagalla Meyen. Philippines.
H. japonica Whitman. Japan.

2. *Mesobdella* R. Blanchard 1893.—With three rings to a somite.

M. gemmata R. Blanchard 1894.

3. *Philæmon* R. Blanchard 1893.—With four rings to a somite.
   P. pungens R. Blanchard. Java and Australia.
   P. grandidieri R. Blanchard. Madagascar.

4. *Phytobdella* R. Blanchard 1893.—With six rings to a somite.
   P. meyeri R. Blanchard. Luzon.
   P. moluccensis R. Blanchard. Salawati.

5. *Planobdella* R. Blanchard 1894.—With seven rings to a somite.
   P. quoyi R. Blanchard. North Celebes.
   P. molesta R. Blanchard. Celebes.

6. *Moquinia* R. Blanchard 1881.—With seven and a half rings between genital apertures.

The remaining orders, Histriobdellida, Acanthobdellida, and Branchiobdellida, do not concern us.

PHYLUM: ARTHROPODA v. Siebold and Stannius 1845.

Bilaterally symmetrical metazoa, with well-developed body cavity and heteronomously segmented body with hollow segmental appendages, moved by intrinsic muscles and penetrated by blood spaces. One or more pairs of appendages behind the mouth are densely chitinized and turned inwards so as to act as jaws.

The phylum Arthropoda is divided into the following grades and classes by Ray Lankester:

GRADE A. PROTARTHROPODA Lankester.
Class I. Onchophora.

GRADE B. EUARTHROPODA Lankester.
Class II. Diplopoda.
Class III. Arachnida.
Class IV. Crustacea.
Class V. Chilopoda.
Class VI. Hexapoda.

The Onchophora, which includes the genus *Peripatus*, does not concern us, but the other classes all contain species of importance in medicine.

CLASS II. DIPLOPODA Ray Lankester 1904.

Synonym.—*Chilognatha.*

Euarthropoda, in which the somites generally fuse after early development, forming double somites, with two pairs of appendages, or present legless and leg-bearing somites alternately. They are terrestrial, breathing by tracheæ.

The following orders are recognized: (1) Juliformia; (2) Symphyla and (3) Pauropoda. We shall only consider the first.

Order I. Juliformia—*Diplopoda with two pairs of appendages on each somite.*—Two families of the Juliformia need be mentioned:

FAMILY JULIDÆ—*Juliformia with large free head, without broad dorsal plates.*—Two species of Julus—viz., *J. terrestris* L. and *J. londinenensis* Leach—have been found as occasional parasites (accidental) in the human alimentary canal in Europe.

FAMILY POLYDESMIDÆ—*Juliformia with large free head and laterally ex-*

tended dorsal plates.—Polydesmus complanatus has once been recorded as an accidental parasite in the human alimentary canal in Europe.

Pathogenesis.—These parasites give rise to symptoms both direct and reflex.

CLASS III. ARACHNIDA Lamarck 1815.

Euarthropoda with two pre-oral segments, the first bearing typical eyes, and the second antennæ or chelicerae, and six post-oral appendages, modified so as to function as jaws, but possessing also a well-developed ramus, which may be a leg, palpus, or chela. The primitive forms have branchial respiratory processes, and the higher pulmonary organs.

The Arachnida are classified by Lankester into:

- Grade A. Anomomeristica.
- Grade B. Nomomeristica.
  - Subclass I. Pantapoda.
  - Subclass II. Euarachnida.
    - Grade *a*. Hydropneusta.
    - Grade *b*. Aëropneusta.
      - Section A. Pectinifera.
        - Order Scorpionidea.
      - Section B. Epectinata.
        - Order I. Pedipalpi.
        - Order II. Aranea.
        - Order III. Palpigrada.
        - Order IV. Solifuga.
        - Order V. Pseudoscorpiones.
        - Order VI. Podogona.
        - Order VII. Opiliones.
        - Order VIII. Acarina.
        - Order IX. Linguatulida (Incertæ sedis).

Details with regard to this classification may be obtained by reference to Ray Lankester's paper in the *Quarterly Journal of Microscopical Science*, 1904, vol. xlviii., p. 165.

We have already considered the effects of the bites of the Scorpionidea, the Aranea, and some of the Acarina, and now it is necessary to consider more particularly those which are parasitic, and cause or spread disease.

Two orders must be dealt with in some detail—viz., the Acarina and the Linguatulida.

ORDER: ACARINA.

Synonym.—Rhynchostomi.

Degenerate Arachnida with the basal segments of the second pair of appendages united in the middle line behind the mouth, while those of the third, fourth, fifth, and sixth appendages are widely separated, and take no part in mastication. The respiratory stigmata usually belong to the prosoma, and the primitive segmentation of the opisthosoma has either entirely or almost entirely disappeared.

The Acarina include the mites and ticks which have long been known to be human parasites, but it is only recently that the latter have come into notice as carriers of disease.

It is true that a mite, or rather its larva, has long been suspected to be the cause of Tsutsugamushi disease, but it is probable that at present we are not fully aware of the disease carrying and producing effects of these small arachnids.

The Acarina are cosmopolitan in their distribution, and are said to be most numerous in temperate regions. They are abundant at high altitudes. Banks remarks that the parasites follow the distribution of the host—*i.e.*, of the food—a remark the importance of which has already been noted (p. 345). The observer will find that a parasitic disease is often bounded by the distribution of the food of the insect, which spreads the real cause of the disease.

Morphology.—The morphology is described under the heading Ixodoidea.

Life-History.—The female lays eggs covered by a shell and an inner membrane called the deutovum. A six-legged larva hatches out from the egg, and after a time, during which it may be active or quiescent, moults and produces the nympha, which is eight-legged, and resembles the adult, except in the non-development of the sexual organs and apertures. The leg which is added to the nympha is the fourth, or posterior. The nymph is usually energetic, and feeds on some host; eventually passing into a quiescent stage and undergoing considerable histological changes, it moults and becomes the adult male or female. The males are usually smaller and more active than the females. Both sexes suck fluid nourishment from the host, whether animal or plant. Their life-history will be found to vary with the different families and species.

Pathogenesis.—The Acarina are important in the dissemination of disease both among men and animals. In men they are responsible for the spread of such fevers as Dutton's relapsing fever, the tick fever of the Rocky Mountains, Tsutsugamushi disease, and the disease associated with the Miana bug in Persia; also they are responsible for a number of skin diseases, among which may be mentioned scabies. In animals they are responsible for the spread of the Babesiases, and some Spirochætiases, as well as causing skin diseases. Incidentally it may be mentioned that they also cause disease in plants, producing galls, etc.

Enemies.—Hurtful as they are themselves, they are not, however, free from persecution on the part of other animals. Blood-sucking insects, particularly the Reduviidæ, prey on these arachnids, sucking their blood. Wellman has reported that he has caught *Phonergates bicoloripes* Stäl in the act of sucking the juices of *Ornithodoros moubata*, the tick responsible for the spread of Dutton's relapsing fever.

The order Acarina is divided into the following suborders:

SUBORDER I. NOTOSTIGMATA.—Acarina in which the opisthosoma is segmented by ten integumental grooves, of which the anterior four are furnished with a single pair of dorsally placed spiracles. (Family: Opilioacaridæ.) This suborder does not concern us.

SUBORDER II. CRYPTOSTIGMATA.—Acarina with a hard integument strengthened by chitinized dorsal and ventral sclerites. Stigmata on the acetabula of the third, fourth, fifth, and sixth pairs of appendages. (Family: Oribatidæ.) This also does not concern us.

SUBORDER III. METASTIGMATA.—Acarina with a hard integument like the Cryptostigmata. One pair of stigmata above and behind the base of the fourth, fifth, or sixth pair of appendages.

Superfamily A. Gamasoidea.
Superfamily B. Ixodoidea.

SUBORDER IV. PROSTIGMATA.—Acarina with soft integument strengthened by special sclerites, those on the ventral surface of the prosoma apparently representing the basal segments of the legs embedded in the skin. Except in the aquatic species, there is a pair of stigmata close to or above the first pair of appendages.

Superfamily A. Trombidoidea.
Superfamily B. Eupopoidea.

SUBORDER V. ASTIGMATA.—Degenerate Acarina, mostly parasitic, like Prostigmata in the development of integumental sclerites and the softness of the skin, but with the respiratory system absent. (Superfamily: Sarcoptoida.)

SUBORDER VI. VERMIFORMIA.—Degenerate parasitic Acarina without respiratory system, and with the body produced posteriorly into an annulated caudal prolongation. With the third, fourth, fifth, and sixth pairs of appendages short, and only three jointed. (Family: Demodicidæ.)

SUBORDER VII. TETRAPODA.—Degenerate atracheate Acarina with body as in the Vermiformia, but with the third and fourth pairs of appendages long and normally segmented, and the fifth and sixth entirely absent. (Family: Eriophyidæ.) This suborder, however, need not concern us.

SUBORDER III. METASTIGMATA.

The parasites included in this suborder would in popular language all be called ticks.

It is divided into two superfamilies:

A. GAMASOIDEA.—With a small hypostome without teeth.

B. IXODOIDEA.—With a large hypostome armed with many recurved teeth.

SUPERFAMILY A. GAMASOIDEA.

The superfamily Gamasoidea is divided into three families: (1) Dermanyssidæ, (2) Uropodidæ, (3) Gamasidæ.

Family I. Dermanyssidæ.

Gamasoidea parasitic on vertebrates, with mandibles fitted for piercing, with the body sometimes constricted, with soft integuments finely striated.

The Dermanyssidæ are divided into two subfamilies: Dermanyssinæ, with an anal plate; Halarachninæ, without an anal plate.

Subfamily Dermanyssinæ.

Dermanyssus Dugès.

Dermanyssinæ with a long body not distinctly constricted; peritreme on the venter, with chelate mandibles in the male and long stiliform mandibles in the female. Parasitic on birds.

Dermanyssus gallinæ de Geer 1778.

Synonyms.—*Pulex gallinæ* Redi 1674, *Acarus gallinæ* de Geer 1778, *Dermanyssus avium* Dugès 1836.

This parasite lives in cracks, etc., in the hen-house during the day, and attacks the fowls at night, sucking the blood. It is also found on many other birds and mammals, and occasionally on man, generally on poultry-men, in whom it produces a papular eczematous dermatitis on the back of the hands and forearms. *D. hirudinis* Hermann 1804, which is probably only a variety of this species, can also be found on man.

Morphology.—Body egg-shaped, posterior end wider than anterior, abdomen with short, marginal, widely separated bristles.

Male 0·6 millimetre by 0·32 millimètre; female, 0·7 millimetre by 0·4 millimetre.

Holothyrus coccinella Gervais 1842.

This arachnid is found on ducks and geese in Mauritius, and is said to attack human beings, causing swelling of the affected part, which, if the lips or tongue of a child, may be dangerous.

SUPERFAMILY B. IXODOIDEA Banks 1894.

Synonyms.—*Riciniæ* Latreille 1804 *pro parte*, *Ixodides* Leach 1815, *Ixodea* Burmeister 1837, *Ricini* Koch 1847, *Ixodida* Küchenmeister 1855, *Ixodidæ* Gerstäcker 1863, *Ixodides* Mégnin 1876, *Ixodæ* Wagner 1876, *Metastigmata* Canestrini 1892, *Cynorhæstea* Marx 1892.

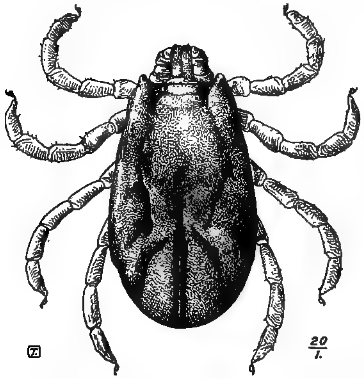

Fig. 184.—Margaropus annulatus Say, variety australis.
Dorsal view of the male.

The term *Cynorhæstea* is derived from Aristotle, who speaks of these arachnids as κυνοραίστης (the dog-tormentors), because ticks were well known in his day to attack hunting-dogs.

The Ixodoidea are the ticks, which have become of importance in tropical medicine not merely because of their unpleasant bite, but because of the spread of disease by their agency—as, for example, the tick fever of Africa, Tsutsugamushi disease, the tick fever of the Rocky Mountains, etc. They are parasitic on mammals, birds, and reptiles, but are not strictly confined to one host. The Argasidæ, one of the two families included in the superfamily, are now nocturnal in habits, and do not become greatly distended with blood; while the other family, Ixodidæ, or true ticks, are very common in tropical countries.

Morphology.—A tick is divisible into a head, rostrum, or capitulum, and a body. The capitulum is the small anterior structure with the mouth parts, and is easily visible from above in the Ixodidæ, but must be viewed from below in the Argasidæ. It joins the rest of the body at the camerostome. The capitulum consists of the following parts:

1. *Neck.*—This is the junction of the rostrum with the rest of the body.

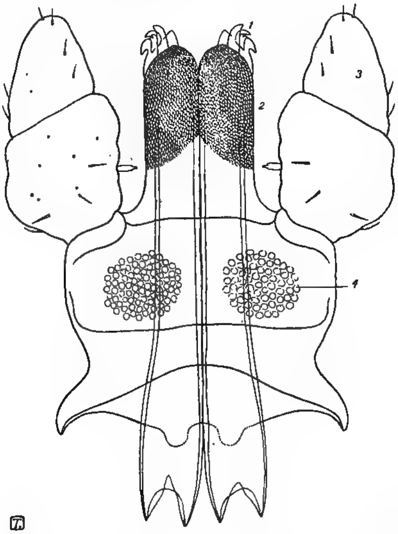

FIG. 185.—DORSAL VIEW OF THE CAPITULUM OF A TICK (HÆMAPHYSALIS PUNCTATA C. AND F.).

(After Nuttall, Cooper and Robinson, *Journal of Parasitology.*)

1, Cheliceræ; 2, hypostome; 3, palp; 4, porose area. (The ventral aspect of this capitulum is shown in Fig. 23.)

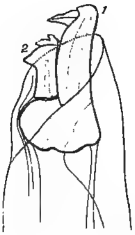

FIG. 186.—CHELICERA OF H. PUNCTATA C. AND F.

(After Nuttall, Cooper and Robinson, *Journal of Parasitology.*)

2. *Base.*—This is the hard basal portion, and is usually quadrangular, but its outline varies.

In females of the Ixodidæ there are two porose areas on the upper surface. Attached behind the base is the neck; in front, in the middle line, is the haustellum, composed of the hypostome and the mandibles and their sheaths, on each side of which lie the palpi.

3. The hypostome is an elongated structure composed of two symmetrical halves, with numerous minute teeth, called denticles, on its ventral surface.

4. The Cheliceræ, or Mandibles, are two in number—one on each side of the median line, lying dorsal to the hypostome. The posterior portion enclosed in the body is swollen for the attachment of muscles, while the anterior is flat and narrow, and terminated by a hook-like digit, which has two or three processes—the apophyses—an internal, an external, and a middle, with hook-like teeth.

5. The mandibular sheath lies dorsal to the mandibles.

6. The palpi are composed of four segments or articles—basal, antepenultimate, penultimate, and apical. They are of importance in classification into genera, as they possess hairs, bristles, edges, angles, and spines, varying in different species. There is sometimes a group of long hairs on the internal aspect of the palpi, which are probably sensory.

The body varies greatly in form, colour, outline, and structure. It is divided into: (1) Dorsal surface; (2) ventral surface; (3) to (5) anterior, posterior, and lateral margins.

1. *Dorsal Surface.*—On the dorsal surface may be noted:

(*a*) The scutum, found in the *Ixodidæ*, and well marked in the adult male, but much smaller in the adult female. It is a hard, chitinous plate, with two longitudinal grooves (cervical grooves).

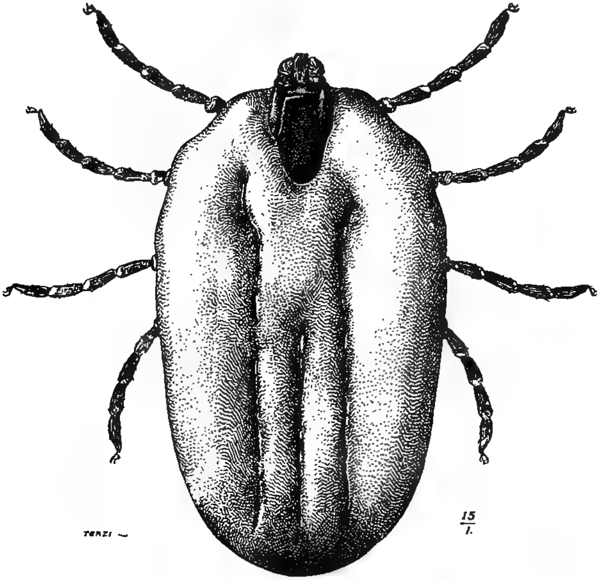

FIG. 187.—MARGAROPUS ANNULATUS SAY AUSTRALIS. Distended female.

(*b*) The eyes, only sometimes present on each lateral margin of the scutum in Ixodidæ, or near the first coxa in Argasidæ.

(*c*) The dorso-submedian porose plates are small, circular, or oval chitinous structures on each side of the median line, near the third and fourth legs.

(*d*) The postero-marginal festoons, when present, are eleven areas marked out by grooves lying along the posterior margin of the body between the stigmata.

(*e*) The dorsal grooves are usually longitudinal, and not always distinct, as they are due to muscular contractions.

(*f*) Pits, hairs, spines, etc., may be visible on the dorsal surface.

2. *The Ventral Surface.*—The ventral surface exhibits (*vide* Fig. 195):

(*a*) The genital pore, situated in the ventro-median line, between the coxæ of the first three pairs of legs.

(*b*) The anus, situate in the ventro-median line behind the posterior pair of legs. It is surrounded by a valve, and in the male of certain genera has laterally the clypea or anal valves.

(*c*) The ventral shields of chitin are small sclerites covering the surface in the male.

(*d*) The stigmata lie one on each side of the body, between the 3rd and 4th pairs of legs in the Argasidæ, and behind the fourth in the Ixodidæ.

(*e*) There are often to be seen a pair of genital furrows and an anal furrow.

(*f*) Pits, pores, hairs, and punctations are to be found as on the dorsal surface.

3. *Anterior Margin.*—This varies as compared with the posterior, being sometimes straighter, sometimes emarginate, and receiving at the camerostome the rostrum.

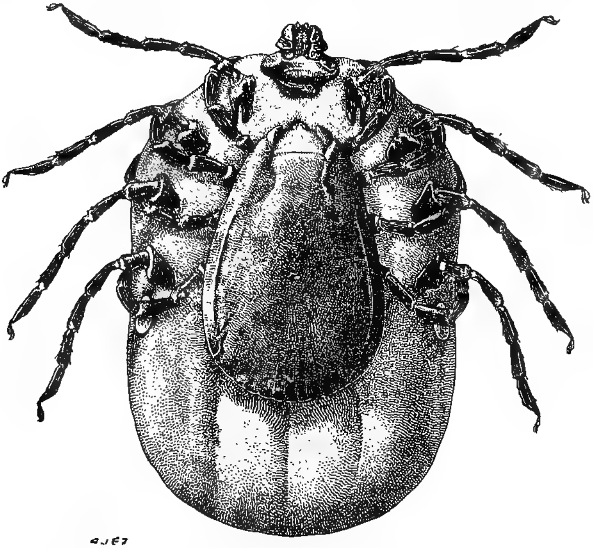

FIG. 188.—COPULATION OF THE MALE AND FEMALE TICK.
(After Sambon.)

4. *Posterior Margin.*—This is generally rounded, and often marked by the festoons already mentioned on the dorsal surface.

5. *Lateral Margins.*—They vary as to their straightness or degree of curvature.

The legs are segmented into the following articles : coxa, trochanter, femur, patella, tibia, and tarsus.

Internal Anatomy.—The internal anatomy has been recently studied by Christophers in *Ornithodoros savignyi*, and most elaborately by Bonnet in eight Ixodidæ and three Argasidæ, males and females.

The tegument consists of chitinous layers, under which lies the epidermis. On the surface are the openings of numerous glands. A large cephalic gland is present in some species, opening dorsally at the junction of the rostrum with the body.

The mouth, which is lined with chitin, is situated anteriorly between the mandibular sheath dorsally and the hypostome ventrally. In this position it is merely a horizontal slit, with open sides, but farther back these are closed by the junction of the hypostome with the mandibular sheaths. The cavity extends backwards some little distance, and ends blindly. Into its postero-lateral angles open the ducts of the salivary glands, two large racemose glands lying over the bases of the first pair of legs. The acini are globular, and their walls consist of large cells, as a rule laden with refractile granules staining deeply, or with indistinct granules staining less deeply.

In addition to the ordinary acini, there are groups of four or five cells, forming pear-shaped masses, which have a peculiar affinity for acid stains like eosin. These elements are really unicellular glands, which open into the principal salivary ducts, not into the small ductules. These glands, which are numerous in the Argasidæ, are probably poison glands.

On the floor of the mouth is a V-shaped opening, apex pointing forwards, which leads into the pharynx. This is a fusiform organ, narrow in front, where it turns upwards to open into the mouth, while behind it ends in the œsophagus. Its walls consist of chitinous plates arranged ventrally and laterally, so that the lumen is triradiate on transverse section. At the angles the chitinous plates are united together by double folds, allowing expansion and contraction, and brought about by the contraction and relaxation of muscles taking origin in the sclerites forming the endoskeleton of the head, and inserted into these plates. It ends posteriorly in a narrow œsophagus, which is without chitinous support, and therefore soft. This œsophagus runs backward, perforating a large ganglionic mass, and ends in the mid-gut. Its walls are composed of a layer of columnar cells internally and by muscular fibres externally. Just before it joins the mid gut its wall thickens and forms a fold, the homologue of the proventriculus, which projects into that passage.

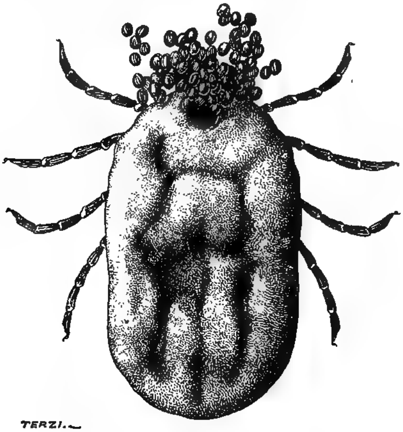

FIG. 189.—A TICK LAYING EGGS.
(After Sambon.)

The œsophagus opens on the floor of the large central food reservoir or mid-gut, the main canal of which runs forward a little distance in front of this opening, and backwards to the neighbourhood of the rectum.

The central canal gives off diverticula, which may be classed into an anterior set, consisting of a single diverticulum; a lateral set, consisting of an antero-lateral diverticulum, subdivided into three branches—a medio-lateral, into two or three, a postero-lateral, which is single, and a posterior set, which is also single.

The walls of the central tube and the diverticula consist of a single layer of large cells lying upon a thin basement membrane, external to which are large single muscular fibres arranged longitudinally and transversely in an open network. Digestion is assisted by free cells mingling with the coagulated blood filling the diverticula.

Posteriorly the central canal is connected with the rectum by means of a very fine canal, which appears to represent a functionless rudimentary intestine. This communication is not admitted by Bonnet.

Into the rectum open also two long, fine, much convoluted tubules—the Malpighian tubes, which are composed of a single layer of large cells placed on a basement membrane. In females they may contain spherical corpuscles, which, though present in males, are much smaller. Berlese and Bonnet consider that these bodies are composed of guanine.

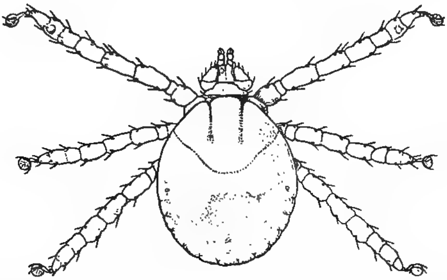

FIG. 190.—THE LARVA OF HÆMAPHYSALIS PUNCTATA C. AND F. (× 40). (After Nuttall, Cooper, and Robinson, *Journal of Parasitology.*)

The rectum is a sacculated tube, with a wall composed of a single layer of flattened cells leading to the anus. Bonnet objects to the term 'anus,' considering the tubules as renal, the rectum as a bladder, and the opening as an excretory pore; but this term must be kept, for morphological reasons. Further, he states that this excretory matter is only expelled during moulting, collecting at other times in the rectum. The anus is a slit-like aperture, guarded by two lateral semicircular chitinous plates.

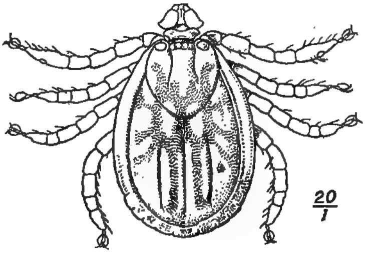

FIG. 191.—THE NYMPH OF HÆMAPHYSALIS PUNCTATA C. AND F. (After Nuttall, Cooper, and Robinson, *Journal of Parasitology.*)

The male reproductive organs consist of a thin, transparent tubule—the testes—ending at either end in a vas deferens, which, after coiling upon itself, enters a lobulated structure—the white gland. The ejaculatory duct ends in the chitinous penis. The female reproductive organs consist of a single ovary, which lies across the abdomen, just behind the central alimentary sac. This ends in two coiled oviducts, which open into a large spermatheca with thick walls, and from which a duct leads to the genital opening.

The tick breathes by means of a system of tubes lined by a spiral thread of chitin. These tubes are called tracheæ, and radiate, from the opening on the stigma called the 'spiracle,' all over the body. The circulatory system consists of a median heart and distributing vessels. The fat body is well marked.

There are a number of dermal glands, a coxal gland in the second coxal joints and opening on the first coxal joints by a minute pore, and a cephalic gland in the head.

Life-History.—While on the host sucking blood, the male and female parasites copulate, and the latter, growing to a large size, drops to the ground and lays a number of eggs. The egg consists of a shell with an inner membrane, enclosing food-yolk and embryo, which eventually hatches as a six-legged larva, without sexual organs or stigmata. The digestive organs are, however, present, and the little larva, becoming parasitic on some animal, sucks its blood, drops off and moults, giving rise to the nympha. The nympha has eight legs and a pair of large stigmata, but is without reproductive openings or organs. The nymphæ now become parasitic, and feed, after which they drop off, moult, and become males or females with fully developed generative organs.

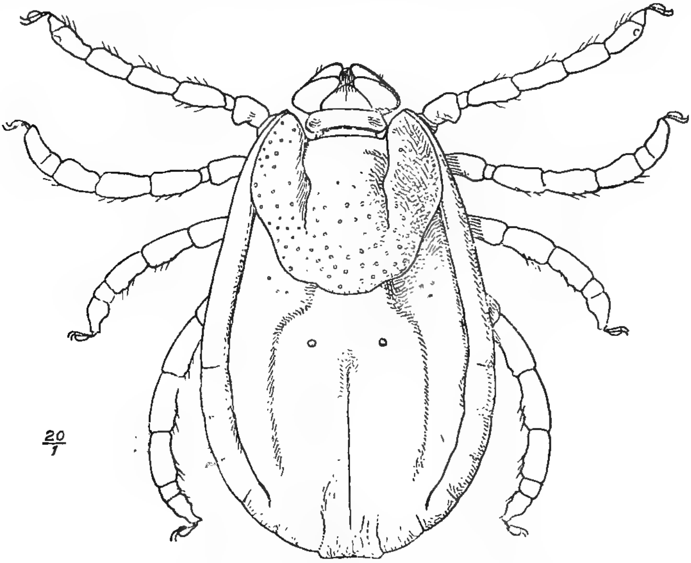

FIG. 192.—ADULT MALE OF HÆMAPHYSALIS PUNCTATA C. AND F.
(After Nuttall, Cooper, and Robinson, *Journal of Parasitology*.)

The adults now become parasitic and moult, and the young female, fixing itself to the host, grows considerably, but rarely changes her place ; while the male, remaining small, wanders about looking for the female.

The life-history and the habits of the different divisions of the *Ixodidæ* are so various that they will be described under their separate heads. One example may, however, be mentioned here—

viz., *Margaropus decoloratus*—whose life-history has been studied by Lounsbury. In this species the female, dropping off the host, completes oviposition in a time varying, according to the temperature of the air, from five days to four weeks, while the incubation of the egg varies from three weeks to three months. The larvæ, which are capable of remaining on grass without food for months, must obtain access to cattle, on which they feed, and grow for three days, after which they moult and form nymphs on the sixth day of their parasitic existence—*i.e.*, without leaving the host. The nymph sucks blood and grows till the eleventh day, and the adult is hatched on the thirteenth to sixteenth day without the nymph leaving the host.

Pairing takes place on the seventeenth to twentieth day, and the fertilized gorged female drops off the host on the twenty-fourth to thirty-first day. Thus, in this case the larva and nymph remain parasitic on the host, and do not drop off as described above.

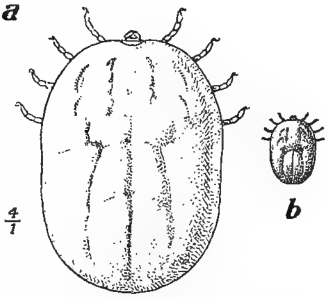

Fig. 193.—Female of Hæmaphysalis punctata C. and F.
(After Nuttall, Cooper, and Robinson, *Journal of Parasitology*.)
(*a*) Magnified; (*b*) natural size.

Parasitic on Man.—The ticks known to be parasitic on man are: (1) *Argas reflexus* Fabricius; (2) *A. persicus* Fischer de Waldheim; (3) *Ornithodoros savignyi* Audouin; (4) *O. moubata* Murray; (5) *O. megnini* Dugès; (6) *O. turicata* Dugès; (7) *O. tholozani* Laboulbène and Mégnin; (8) *Alectorobius talaje* Guèrin-Méneville; (9) *Eurhipicephalus sanguineus* Latreille; (10) *Margaropus annulatus*; (11) *Dermacentor reticulatus* Fabricius; (12) *D. occidentalis* Marx; (13) *D. electus* Koch; (14) *Euïxodes ricinus* Linnæus; (15) *E. hexagonus* Leach; (16) *Amblyomma americanum* Koch; (17) *A. dissimile* Koch; (18) *Hyalomma ægyptium* Linnæus.

Pathogenesis.—Ticks are spreaders of disease in man and animals. They may be classified into spreaders of *Spirochætæ*, spreaders of *Babesia*, and into spreaders of unknown germs.

1. Spreaders of Spirochætæ.

1. *Ornithodoros moubata* carries *Spirochæta duttoni*, and causes African tick fever or Dutton's relapsing fever in man.
2. *Argas persicus* carries *Spirochæta marchouxi* Nuttall 1904.

2. Spreaders of Babesia.

1. *Eurhipicephalus appendiculatus* carries *B. bigeminum.*
2. *E. simus.*—*B. bigeminum.*
3. *E. evertsi.*—*B. equi.*
4. *E. sanguineus.*—*B. canis.*

5. *E. bursa.—B. ovis.*
6. *Margaropus annulatus.—B. annulatum.*
7. *Hæmophysalis leachi.—B. canis.*

3. Spreaders of Unknown Germs.

1. *Argas persicus* causes a disease in Persia.
2. *Dermacentor occidentalis* causes Rocky Mountain fever.

Classification.—The Ixodoidea are divided into two families:

Family 1. Argasidæ Canestrini 1890.—Ixodoidea without a scutum; mouth parts of adult not prominent from above; no pulvillus attached to tarsus in adults.

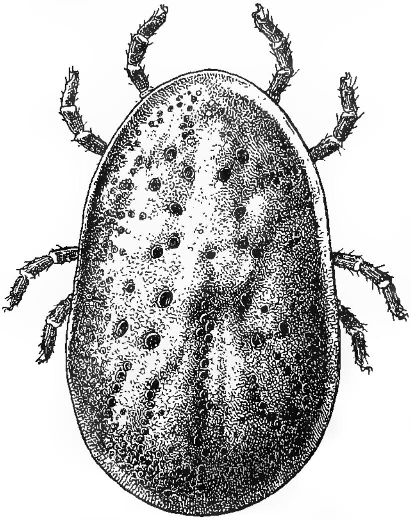

Fig. 194.—Argas persicus Latreille: Female Dorsal Aspect (Modified).

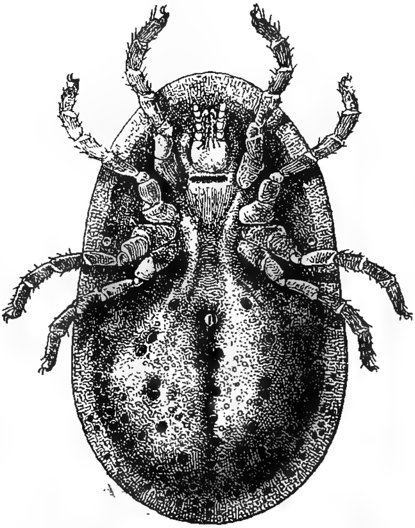

Fig. 195.—Argas persicus Latrielle: Female Ventral Aspect.

Family 2. Ixodidæ Murray 1877.—Ixodoidea with a scutum; mouth parts prominent from above; pulvillus present, attached to the tarsus in adults.

Family 1. Argasidæ.

These arachnids are more like bugs than ticks in their habits. During the day they are concealed in cracks in walls or floors, or in gravel, but at night they come out and run about. Christophers says that if handled they sham death, and that when running about they have a curious habit of raising the first pair of legs as though to receive information about their surroundings. They can live for a long time (three to four years) without food. They generally feed after dark, being gorged in about fifteen minutes.

Donovan states that while feeding fluid is secreted by the coxal glands, and lies between the parasite and the skin of the host. This fluid is alkaline, and prevents coagulation of blood. After feeding, the tick drops to the ground, and, being wet with secretion, becomes covered with dust and dirt. At first they are much swollen, but in a few days this diminishes, though they may remain distended for weeks. Soon after feeding, the tick moults, and then becomes active again, and is ready for another feed.

The Argasidæ pair at various times, one female being fertilized by several males. The female now becomes quiescent, and passes out its ova, a process requiring a week or more to be completed. During this process the head is forcibly flexed on the body, so that the palpi lie on each side of the body, while above the head is the prolapsed duct of the cephalic gland, forming a protuberant mass. The ova are not as numerous as those of the cattle ticks, and are generally laid in a loosely adherent mass.

The six-legged larva hatches in less than a week. In *Ornithodoros* it appears to be quiescent, making no attempt to obtain food, and in *O. moubata* does not leave the egg. In three or four days it moults, and becomes the eight-legged nymph, which is an active little creature, feeding readily. In *Argas* the larva is more vigorous, and feeds. It appears as though there were great differences in the life-history of the different species of the Argasidæ.

The adult Argasidæ appear to moult many times as they grow larger. They are preyed upon by insects.

Genera.—The Argasidæ are divided into four genera: *Argas, Caris, Ornithodoros, Alectorobius.*

The diagnosis of these genera is as follows:

1. Eyes absent, body usually flat, with thin borders, without deep ventral grooves: (*a*) No groove behind anus—*Argas*; (*b*) transverse groove behind anus—*Caris.*

2. Eyes present or absent; body more or less distended, with deep ventral grooves: (*a*) Without a fold of skin (sclerite) on each side of palpi—*Ornithodoros*; (*b*) without such a fold—*Alectorobius.*

There is, however, some doubt as to whether *Caris* is really entitled to be a separate genus.

Argas Latreille 1796.

Synonyms.—*Nec* Scoul 1835, *Carois* Latreille 1796, *Rhynchoprion* Hermann 1804, *Caris* Latreille 1806.

Definition.—Argasidæ with oval or flattened bodies, in which the rostrum is at least its own length from the anterior margin, which is less bluntly rounded than the posterior margin. No fold present around the base of the rostrum ventrally. Tegument roughened by wrinkles and folds, and marked by circular pits. Without eyes.

Type.—*Argas reflexus.*

The number of species known is steadily increasing. The more important can be defined by the following table, modified from Neumann :

- A. Posterior margin with rectangular festoons—*A. persicus.*
- B. Posterior margin with narrow festoons :
  - I. Tegument with fine folds, body long, swollen—*A. hermanni.*
  - II. Tegument with large folds, body flat :
    - (α) Body narrower in front :
      - (1) Anterior extremity flat and rounded—*A. reflexus.*
      - (2) Anterior extremity pointed :
        - (*a*) With deep camerostome and dorsal hexagonal markings—*A. brumpti.*
        - (*b*) Without these—*A. æqualis.*
    - (β) Body almost as large in front as behind :
      - (1) Body short, a little longer than broad—*A. transgariepinus.*
      - (2) Body twice as long as broad—*A. cucumerinus.*

Argas reflexus Fabricius 1794.

Synonyms. — *Acarus reflexus* Fabricius 1794, *A. marginatus* Fabricius 1794, *Rhynchoporion columbæ* Hermann 1804.

Argas with yellowish body ; male 4 by 3 millimetres, female 6 to 8 by 4 millimetres. Its distribution is mainly in Europe and America, where it lives in dovecots ; but it can and does attack man, producing the symptoms already described (p. 141).

Argas persicus Oken 1818.

Synonyms.—*Rhynchoprion persicum* Oken 1818, *Argas persicus* Fischer de Waldheim 1820, *A. mauritianus* Guérin-Méneville, *A. miniatus* Koch 1844, *A. americanus* Packard 1872, *A. sanchezi* Dugès 1891, *A. chinche* Gondet.

This *Argas* is widely distributed, being found in Asia, where, under the term 'garib-guez' (*punaise de Miana*), it has long had an evil reputation for causing sickness. It is also known in Quetta. In South Africa it occurs as a parasite of fowls and ducks, and is also known in the Sudan, Egypt, Turkestan, and Pekin. Under the name of *A. miniatus* it was described in the form of the chicken tick of the United States, and the adobe tick of Mexico and Arizona. According to Balfour, it spreads the *Spirochæta marchouxi* in Sudanese fowls. Nuttall and Strickland have demonstrated the presence of an anticoagulin in the salivary glands and intestine of this tick.

Argas with oval, brownish-red body. Male 4 to 5 by 3 millimetres ; female 7 to 10 by 5 to 6 millimetres. Dorsal and ventral surfaces with pits in rows, and irregularly placed.

Argas brumpti Neumann 1907.

This tick was discovered by Brumpt in Somaliland. The dorsum is marked by symmetrical hexagonal depressed areas. Female, 20 by 13 millimetres. Nuttall says that, according to Brumpt, the bite is very painful, and causes pruritus lasting several days, and the site may remain indurated after seven years.

Argas cucumerinus Neumann 1901.

Only the male of this tick is known. It has an oval elongated body, brownish-red in colour, 10 by 5 millimetres. It is found in Lima in Peru. Possibly this is merely a variety of *A. reflexus.*

Argas hermanni Audouin 1827.

Argas with very fine skin-folds and small rostrum. It is found in Abyssinia and Egypt. Possibly this also is only a variety of *A. reflexus.*

Argas æqualis Neumann 1908.

Synonym.—*Ornithodorus æqualis* Neumann 1901.

Nuttall places this species with the Argasidæ. It was found in German East Africa by Fülleborn. In size it is 5 by 2·5 millimetres, with folded finely granulated integument.

Argas transgariepinus White 1846.

Synonym.—*Argas kochi* Neumann.

Argas with very compressed body, not much longer than broad —7·5 by 6 millimetres. Margin with irregular folds. Found in South Africa.

Caris Latreille 1804.

Argasidæ with almost circular body, a little larger in front than behind, with a conspicuous transverse groove behind the anus.

Caris vespertilionis Latreille 1796.

Synonyms.—*Carios vespertilionis* Latreille 1796, *Argas pulchella* George 1876.

Parasitic on bats.

Ornithodoros Koch 1844.

Argasidæ with or without eyes. Rostrum surrounded ventrally by a camerostome. Tips of the palpi visible from above. Lateral borders of the body straight, sometimes concave. Integument mammillated, with hemispherical elevations. Two longitudinal coxal folds, a pair of supracoxal folds, one transverse pre-anal and one post-anal groove, and one longitudinal anal groove running from the anus to the post-anal groove.

Type.—*Ornithodoros savignyi* Audouin 1827.

Eleven species are recorded: (1) *Ornithodoros savignyi* Audouin 1827; (2) *O. moubata* Murray 1887; (3) *O. turicata* Dugès 1876; (4) *O. megnini* Dugès 1883; (5) *O. lahorensis* Neumann 1908; (6) *O. tholozani* Laboulbène and Mégnin 1882; (7) *O. pavimentosus* Neumann 1901; (8) *O. furcosus* Neumann 1908; (9) *O. erraticus* Lucas 1849; (10) *O. coriaceus* Koch 1844; (11) *O. canestrinii* Birula 1895.

DIAGNOSTIC TABLE.

A. Eyes present:
  Three knobs on the last segment of the fourth leg:
    (*a*) Tegument with hemispherical protuberances:
      (1) Eyes of equal size (Africa and India)—*O. savignyi.*
      (2) Anterior eyes larger (America)—*O. coriaceus.*
    (*b*) Tegument with flattened protuberances (Africa)—*O. pavimentosus*

B. Eyes absent:
  I. Subrectangular body nearly square (Mexico)—*O. turicata.*
  II. Body more or less constricted behind the fourth pair of legs:
    (*a*) With broad anterior end (Mexico)—*O. megnini.*
    (*b*) With narrow anterior end (Lahore)—*O. lahorensis.*
  III. Ovoid body, with broader posterior end:
    (*a*) Anterior end broad and rounded (Central Africa)—*O. moubata.*
    (*b*) Anterior end tapering:
      (1) Tarsi forked distally (Ecuador)—*O. furcosus.*
      (2) Tarsi slightly knobbed (Algeria)—*O. erraticus.*
      (3) Tarsi second to fourth markedly knobbed (Persia)—*O. tholozani.*
      (4) Tarsi first with three dorsal knobs, second to fourth with one knob (Persia)—*O. canestrinii.*

Ornithodoros savignyi Audouin 1827.

Synonyms.—*Argas savignyi* Audouin 1827, *Ornithodoros morbillosus* Gerstäcker 1873.

This is the type species of the genus, and has been studied in detail by Neumann and Christophers.

It is common in Africa, India, and Aden, and perhaps elsewhere.

Morphology.—*Ornithodoros*, with two pairs of eyes appearing as circular, smooth, convex elevations, situated on the supracoxal fold above the bases of the first pair of legs, and between those of the second and third pairs. Body oval, constricted slightly between the third and fourth pairs of legs, yellow in colour when young, and blackish-brown when old. Integument covered with irregular hemispherical prominences pointed at their summits, between which are narrow depressions with hairs. Capitulum embedded in an infundibuliform camerostome, from which it is separated by a deep groove, in the dorsal portion of which can be seen the opening of the cephalic gland. Mandibles with a simple claw-like internal apophysis, and without middle apophysis. Teeth of the hypostome arranged in three longitudinal parallel rows. Two spines at the base of the hypostome, which is large.

Dorsum of the body marked by two transverse furrows, one just in front of the posterior border, and the other situate farther forward, marking off a median elevation with a central depression, and seven similar depressions, each of which becomes a deep sulcus posteriorly.

The ventral surface shows a well-marked pre-anal furrow, which laterally meets the supracoxal sulcus, which runs round the anterior aspect of the body as a well-marked groove, defining the supracoxal fold, on which the eyes are situate. Behind the anus are three symmetrical longitudinal grooves, while a short V-shaped depression abuts on the anus. The genital papilla is well marked, and surrounds the wide transverse opening.

The fourth pair of legs is one and a half times as long as the first. The coxæ are contiguous, and diminish in size from the first to the fourth, and the first has the opening of the coxal gland. Christophers has observed that the fluid from this gland is alkaline, and prevents coagulation of the blood. The stigmata are placed behind and above the supracoxal folds. The fifth joints of the first three pairs of legs with three teeth, the two proximal, quadrangular, and the distal conical.

This tick is very hardy, and is said to be able to live for many months without food or moisture. It attacks human beings, and is found in Africa and India.

Pathogenesis.—Not known.

Ornithodoros moubata Murray 1877.

Synonym.—*Ornithodoros savignyi var. cæcus* Neumann 1901.

O. moubata is of importance as the spreader of *Spirochæta duttoni*, the cause of Dutton's relapsing fever, or African tick fever. The tick is distributed widely in Africa, where it is called bibo in Uganda, moubata in Angola, and tampan in Zambesi. Christy has described a similar tick in Brazil.

Morphology.—*Ornithodoros* without eyes, body oval, a little wider behind than in front, with a slight constriction between the third and fourth legs; colour varies with age from yellow-brown to dusky brown. Integument covered with irregular hemispherical prominences. Capitulum embedded in an infundibuliform camerostome. Mandible with external apophyses, with two widely separated teeth, and an internal apophysis, which is bidentate. Hypostome not much wider at the base than at the anterior third. Dorsum of the body marked by two short transverse grooves posteriorly and three pairs of pits, from each of which a sulcus runs backwards and inwards.

The ventral surface shows a well-marked pre-anal sulcus, which joins the supracoxal groove, as in *S. savignyi*; behind the anus are three pairs of longitudinal grooves. The stigmata are semilunar, situate above the supracoxal groove. The last segment of the fourth pair of legs is stout and compressed, with three knobs, the distance between the first and second being equal to that between the second and third.

Tibiæ and tarsi of the first three pairs of legs, with three teeth—proximal, submedian, and distal, the latter being conical.

Life-History.—The female lays a variable number of eggs, from 70 to 139, which adhere together, and are golden-brown in colour: 881 by 776 μ. Inside these eggs the larvæ develop and moult, becoming nymphæ, which hatch about the twentieth day at a temperature of 20 to 30° C. and a humidity of 71 to 77 per cent. After three or four days these nymphæ suck blood. At first the position of the stigma is marked by only a small white spot and pit, but after the first moult this becomes clear. The genital pore is always absent until after the second moult.

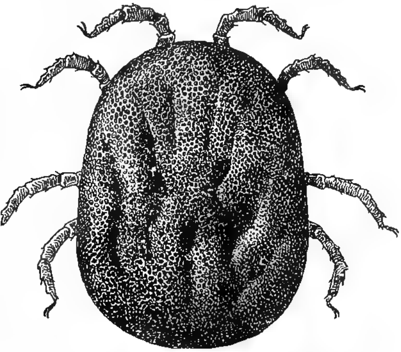

FIG. 196.—ORNITHODOROS MOUBATA MURRAY: FEMALE DORSAL ASPECT (× 4).

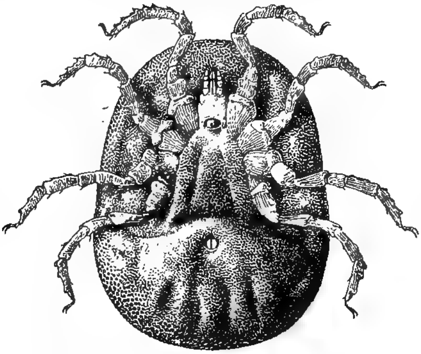

FIG. 197.—ORNITHODOROS MOUBATA MURRAY: FEMALE VENTRAL ASPECT (× 4).

The adult tick moults after each feed of blood, and may live about a year. They are night feeders, and rather resemble bugs in their habits. Leishmann observed that the fluid secreted by the coxal glands prevents coagulation of the blood.

Pathogenesis.—It is the spreader of *Spirochæta duttoni*, and according to Wellman and Feldman possibly of *Filaria perstans*.

Ornithodoros turicata Dugès 1876.

Ornithodoros without eyes; anteriorly the body is much narrowed. Tibiæ and tarsi with three small tubercles.

Habitat.—Mexico and Central America. Attacks men and fowls.

Ornithodoros megnini Dugès 1883.

Synonyms.—*Argas megnini* Dugès 1883, *A. americana* Packard 1893, *Rhynchoprium spinosum* Marx 1895.

Ornithodoros with phial-shaped body; attenuated anteriorly.

Females 5 to 6 millimetres by 3 to 4 millimetres. Males somewhat smaller.

This is the ear tick of American cattle, and has been found in the ear of man.

Ornithodoros lahorensis Neumann 1908.

Ornithodoros without eyes. Male 8 by 4·5 millimetres. Female 10 by 5·6 millimetres. Found at Lahore, India. Parasitic on sheep.

Ornithodoros tholozani Laboulbène and Mégnin 1882.

Synonyms.—*A. tholozani* Laboulbène and Mégnin 1882, *A. papillipes* Birula 1895.

Ornithodoros without eyes. Males 4 to 6 millimetres in length and 2 to 4 millimetres in breadth. Females 8 to 10 millimetres by 4 to 5 millimetres.

It is specially a parasite of sheep in Caucasia and Persia, but is very dangerous to man.

Ornithodoros pavimentosus Neumann 1901.

Ornithodoros with eyes. Body covered with flat warts forming a pavement. South Africa.

Ornithodoros furcosus Neumann 1908.

Found in Ecuador. Female 10 by 5 millimetres.

Ornithodoros erraticus Lucas 1849.

Synonym.—*O. miliaris* Karsch 1880.

Found in Algeria and Bengal. Length, 2·5 millimetres; breadth, 1·7 millimetres.

Ornithodoros coriaceous Koch 1844.

Ornithodoros with eyes. Only one knob on the hind tarsus. America.

Ornithodoros canestrinii Birula 1895.

Synonym.—*Argas canestrinii* Birula 1895.

Found in Persia. Male 10 by 5 millimetres; female 14 by 8 millimetres.

Alectorobius Pocock 1907.

Argasidæ with folds of integument capable of being folded under the palpi.

Type.—*A. talaje* Guérin-Méneville 1849.

Alectorobius talaje Guérin-Méneville 1849.

Synonym.—*O. talaje* Guérin and Méneville 1849.

This is the chinch of South America and Mexico, where it is a great pest. *A. coniceps* of South Europe and *A. capensis* of South Africa are varieties of this species.

SUPERFAMILY B. IXODIDÆ Murray 1887.

Synonyms.—*Ixodei* Dugès 1834, *Ixodini* Canestrini and Fanzago 1877, *Ixodinæ* Trouessart 1892, *Anistomata* Marx 1892.

Ixodoidea with a dorsal scutum and a terminal capitulum. The digit of the mandible has two apophyses, and the palpi are free.

Most of the ticks belong to this family, which has the following features.

Morphology.—There is a dorsal scutum and a terminal capitulum. The mandible has a digit with two apophyses, of which the internal is short, with one to four teeth, and the external long, with two to five teeth. The palpi are free. The second pair of legs is the shortest, and the fourth pair the longest. The tarsus has a pulvillum. The stigmata are situate posterior to the coxa of the fourth leg. The male is smaller and fatter than the female. The scutum covers the whole dorsum except a marginal region, the posterior portion of which, between the two stigmata, is generally divided into eleven festoons. The female has but a small scutum, situated anteriorly, and the capitulum has two symmetrical porose areas on its basal piece.

Type Genus.—*Ixodes* Latreille 1796.

Life-History of the Ixodidæ.—When the pregnant female tick drops off the host, it at first appears to seek for a suitable place to lay its eggs. When this is found, it becomes quiescent, and the anterior part of the ventral surface between the first pair of legs becomes depressed, and forms a hollow, in which the head and genital orifice are situated. When an ovum passes out of the orifice, the tick moves slightly backwards. This oviposition takes about fifteen to twenty days. While it is proceeding the tick begins to shrivel and to show yellow areas, due to the distension of the Malpighian tubes with guanine. At the end of oviposition the tick dies.

From the egg comes a six-legged larva, which generally climbs into some grass or bushes and waits to get on to a host. While so doing, it may remain for months without food.

It now sucks blood, and drops off this first host and moults on the ground, becoming an eight-legged nymph, like an adult, but without generative apparatus, which again has to go in search of a second host and obtain a feed of blood, when it drops off and undergoes a second moult, turning this time into the sexually mature adult, which goes in search of a third host. Before feeding, the adult female is small, flat, and thin. When she arrives on the third host she drives her rostrum perpendicularly into the skin as far as its base, a hole being made by the mandibles.

The palpi do not enter the hole in the skin, but lie on each side.

The recurved hooks on the hypostome keep the tick in position, and can only with difficulty be detached. The tick now sucks the blood, and at the same time becomes fertilized, and increases enormously in size by the addition of blood and the development of the eggs. She then drops off this third host and proceeds to lay her eggs.

The male does not gorge and does not increase so much in size, ut sucks blood, which it requires for its fertilizing work.

The *Ixodidæ* are divided into two subfamilies :

SUBFAMILY I. RHIPICEPHALINÆ Salmon and Stiles 1901.

Synonyms.—*Rhipistomidea* Koch 1844, *Conipalpi* Canestrini 1890, *Rhipicephalæ* Neumann 1897, *Rhipistomidæ* Marx 1896.

Ixodidæ in which the palpi are no longer than broad. Anterior portion of the body emarginate.

Type Genus.—*Eurhipicephalus.*

Genera.—*Eurhipicephalus, Margaropus, Hæmaphysalis, Demacentor, Rhipicentor.*

SUBFAMILY 2. IXODINÆ Salmon and Stiles 1901.

Synonyms.—*Ixodidea* Koch 1844, *Cultripalpi* Canestrini 1890, *Ixodidæ* Marx 1892, *Hæmatustoridæ* Marx 1892, *Eschatocephalidæ* Marx 1892, *Ixodæ* Neumann 1899.

Ixodidæ with palpi longer than broad ; rostrum long. Anterior portion of the body straight or emarginate.

Type Genus.—*Euixodes.*

Genera.—*Euixodes, Eschatocephalus, Ceratixodes, Aponomma, Amblyomma, Hyalomma.*

DIAGNOSTIC TABLE OF GENERA, FROM SALMON AND STILES.

Rhipicephalinæ.

A. Eyes present :

- I. Dorsal surface of capitulum hexagonal, sides drawn out laterally into sharp points. (*a*) Males with anal plates.
  - 1. Second and third palpal segments straight ; stigmata comma-shaped—*Eurhipicephalus.*
  - 2. Second and third palpal segments drawn out laterally into sharp points ; stigmata round—*Margaropus.* (*b*) Males with rudimentary anal plates—*Rhipicentor.*
- II. Dorsal surface of capitulum rectangular, sides straight ; male without anal plate—*Dermacentor.*

B. Eyes absent—*Hæmaphysalis.*

SUBFAMILY RHIPICEPHALINÆ.

Genus.—*Eurhipicephalus.*

Synonyms.—*Rhipicephalus* Koch 1844, *Pauloixodes* Berlese 1889.

Rhipicephalinæ with distinct eyes ; base of the capitulum broader than long ; hexagonal, or dorsal surface forming a projecting angle at each side. Palpi short and broad. First coxa with two large teeth.

Male with two pairs of anal shields.

Type Species.—*Eurhipicephalus sanguineus* Latreille.

Eurhipicephalus appendiculatus Neumann 1901.

This is the brown tick of South Africa, where it spreads *Babesia parva* among cattle and buffaloes, causing 'coast fever.'

Morphology.—Male: Scutum does not quite cover the dorsum; festoons narrow; the median is prolonged into a caudal process. In front of the festoons, three wide longitudinal grooves. Size, 4 by 2·6 millimetres. Female: Dorsal plate oval; porose area small.

Life-History.—The eggs are laid in thousands on the grass, and hatch in about twenty-eight days into six-legged larvæ, which pass from the grass on to cattle, suck blood, and drop off replete in about three to four days.

They now remain dormant for about twenty-one days, and finally moult, giving rise to the eight-legged nymph.

The nymph proceeds to attack cattle and suck blood, taking the same length of time as the larva. It then drops off replete, and in about eighteen days moults and becomes an adult male or female tick, which again infests cattle. The female settles down quickly, and is joined by the male. In about four days the female, which has become fertilized and full of blood, drops off, and completes the life cycle by laying the eggs, after which she dies.

What becomes of the male is not known.

Pathogenesis.—It spreads *Babesia parva*, the cause of coast fever in cattle, by the bites of the infected nymphs only—*i.e.*, infected larvæ and adults do not spread the disease, but the larva can hand the infection over to the nymph, which is the spreader.

Eurhipicephalus bursa Canestrini and Fanzago 1877.

Synonym.—*Rhipicephalus bilenus* Pavesi 1883.

This species is widespread through Southern Europe, and is also known in Africa, West Indies, and Malaga, as a sheep, horse, cattle, and dog tick.

Morphology.—Male scutum half as long as wide; narrow anteriorly, with many punctations. Eleven festoons. Size 4·5 by 3 millimetres.

Female, when newly hatched, flat; when distended with blood, ovoid. Scutum oval; eyes about the middle of the length. Tegument with numerous punctations dorsally when young.

Life-History.—The female lays the eggs on grass, and these develop into larvæ, which attack a sheep, and moult on it in about eight days, forming nymphæ, which grow for twenty-one days, fall off on to the ground, moult, and become adults, which again infest sheep.

Pathogenesis.—It spreads *B. ovis*, which causes 'heart-water' in sheep, the infection being carried from an adult female through the eggs to the adult ticks of the next generation, which alone are capable of transmitting the disease.

Eurhipicephalus simus Koch 1844.

This tick is found in various parts of Africa—viz., Egypt, German East Africa, and the Cape. It has several varieties—*e.g.*, *E. simus erlangeri*, *E. s. hilgerti*, *E. s. shipleyi*. In South Africa it is called the black pitted tick, because of its punctations, and causes 'coast fever' by spreading *Babesia parva*. Male oval, rounded posteriorly; 4 by 2·2 millimetres. Scutum brown-red. Female oval, 6 by 3 millimetres.

Eurhipicephalus sanguineus Latreille 1804.

Synonyms.—*Ixodes sanguineus* Latreille 1804, *I. rufus* Koch 1844.

Synonym of Nymph.—*Phailixodes rufus*.

This is the common dog tick, by which *B. canis* is spread, which it acquires as an adult, and transmits in the succeeding nymphal and adult stages. It also spreads *Hæmogregarina canis*. It is practically cosmopolitan.

The female has an elliptical body, wider in front than behind: 11 by 7 millimetres, reddish-brown in colour. Scutum very small; integument nearly or completely without hairs. The mandibles have an internal apophysis with three teeth, arranged one internally and two externally; and an external apophysis with three teeth, arranged in series.

The male is 3·35 by 1·55 millimetres, with a scutum covering the dorsal surface, except at the sides and back. External apophysis with only two teeth.

Eurhipicephalus evertsi Neumann 1897.

This is the red-leg tick, which spreads *B. equi*, and is found in Europe, Africa, and Asia. The life-history resembles *Eurhipicephalus appendiculatus* in the changes of host by larva and nymph. The infection is acquired in the nymphal stage, and transmitted by the adult. Size: male, 5 to 6 by 3 to 4 millimetres; female, 14 by 9 millimetres.

Margaropus Karsh 1879.

Synonyms.—*Boophilus* Curtice 1891, *Rhipicephalus* Neumann 1897.

Rhipicephalinæ with eyes, though often indistinct; base and capitulum broader than long. Palpi short and broad; second and third segment thicker in the middle, and forming a sharp angle externally. Posterior margin of the first coxa slightly bidentate; stigmal plate round. Body without marginal festoons; anal groove absent. Male with two pairs of anal plates.

Type.—*M. annulatus*.

Only three or, according to Neumann, two species, of which two species (*M. annulatus*, *M. decoloratus*) may be one, the third being *M. lounsburyi* Neumann 1907.

Margaropus annulatus Say 1821.

Synonyms.—*Ixodes annulatus* Say 1821, *Hæmophysalis rosea* Koch 1844, *Ixodes bovis* Riley 1869, *Boophilus bovis* Curtice 1880, and several others.

Female with elliptical body, as wide in front as behind. Scutum very small. Eyes small. Dorsal surface with two antero-posterior grooves, interrupted towards their middle. Ventral surface with small sexual aperture and sexual furrows. Stigmata oval. Capitulum very short. Internal apophysis of mandible conical; the external with three teeth. Hypostome broad. Palpi very short. Legs short (*vide* Fig. 187).

Male with body oval, 2·15 by 2·35 millimetres, narrow anteriorly; widest opposite stigmata. Scutum brown-red, covering the whole dorsal surface with large punctata. Sexual orifice large, a little in front of the level of the second pair of legs. Festoons hardly marked. Two pairs of clypeal shields. Internal apophysis of the mandibles with bifid point; the external has two teeth. Coxa of first leg with a blunt anterior process and bifid posteriorly (*vide* Fig. 184).

This tick has a very wide geographical distribution, being found in North and South America, the West Indies, Africa, Europe, Japan, and Australia; but the different countries show certain variations in the tick, and hence the species receive a little change in the name.

Life-History.—*Margaropus annulatus* begins its life with the egg on the ground from which the larva emerges, and gaining access to the host, undergoes its development into nymph and adult without the changes of host described in *Eurhipicephalus*.

When the adult female has gorged with blood, she drops off the host and lays her eggs.

Pathogenesis.—It is the spreader of *Babesia bigeminum*, the cause of Texas or red-water fever in cattle. The adult female acquires the *Babesia* and passes it on to the larva, which infects the host.

Varieties.—The names of the varieties are: (1) *M. dugesi* Mégnin 1880, in North Africa; (2) *M. microphilus* Canestrini 1887, in South America; (3) *M. australis* Fuller 1899, in Australia, Asia, Africa; (4) *M. calcaratus* Birula 1895, in the Caucasus; (5) *M. caudatus* Neumann 1901, in Japan; (6) *M. argentinus* Neumann 1901, in Buenos Ayres.

Margaropus decoloratus Koch 1844.

This is looked upon as a variety of *Margaropus annulatus* Say by some authors. It is the blue tick of South Africa.

Morphology.—The clypeal plates in the male end in sharp points, and a caudal appendage is present. The hypostome has six rows of teeth.

Life-History.—It lives from the larval stage to the adult on the same host. The adult, when fully fed, drops off and lays the eggs on the ground.

Pathogenesis.—It is a spreader of *Babesia bigemina*.

Rhipicentor Nuttall and Warburton 1908.

A new genus participating in the dorsal characters of Rhipicephalus and the ventral of Dermacentor.

Species.—*Rh. bicornis* N. and W. 1908, *Rh. vicinus* N. 1908.

Dermacentor Koch 1844.

Rhipicephalinæ with eyes; base of capitulum rectangular, broader than long. Dorso-submedian porose plate present; palpi short and thick; stigmata comma-shaped. Male without anal shields. The coxa of the fourth leg much larger than those of the others. Scutum ornamented.

Type.—*D. reticulatus* Fabricius.

Dermacentor reticulatus Fabricius 1794.

Synonyms.—*Acarus reticulatus* Fabricius 1794; *Ixodes reticulatus* Fabricius 1805; *I. marmoratus* Risso 1826; *Dermacentor albicollis* Koch 1844; *D. pordalinus* Koch 1844; *D. ferrugineus* Koch 1844; *Hæmophysalis marmorata* Berlese 1887.

Dermacentor with coarsely punctate stigmal plate.

This tick gains its importance from the fact that for some time it was considered to be the cause of the spread of Rocky Mountain fever, which is really due to the nearly-related *D. occidentalis*, with which it was long confused. It probably does not occur in America. It is widely distributed through Europe and Asia.

Dermacentor occidentalis Marx 1892.

This tick was received by Marx from Occidental in California, and was first described by Neumann. It is found in the north-western portion of the United States, from California to Montana.

Morphology.—Male: Oval, narrow in front, broad behind; scutum variegated brown and white. Anteriorly there is an elliptical area, the pseudo-scutum, closely representing the form and colour of the female scutum, and limited by a white border, and possessing two lateral brown stripes, with a median brown stripe or spots between them. Behind this there are four brown stripes arranged in a curve, open anteriorly. Posterior to these usually five brown stripes; one central and two lateral. Between

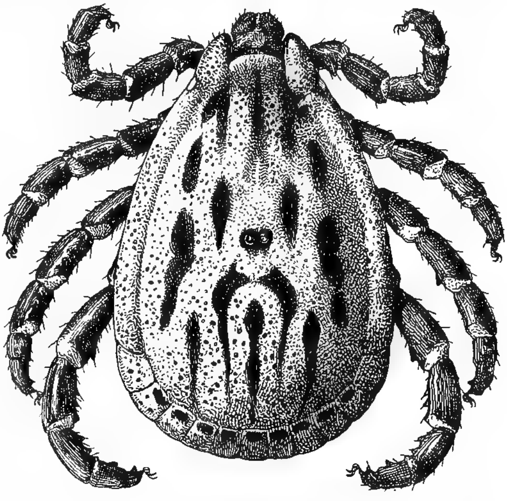

FIG. 198.—DERMACENTOR OCCIDENTALIS (MALE): DORSAL ASPECT.*

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* In a private communication received from Dr. Stiles, he states that this tick will be separated from *D. reticulatus* and *D. occidentalis*, and be named *D. salmoni* Stiles 1909.

these areas the whole dorsum is speckled with brown punctations. The eleven festoons are somewhat quadrangular, each composed of a white area with one brown spot, and speckled with brown punctations. Ventral surface with the first coxa bidentate, and the others with a single spine. Fourth coxa very large; about twice as large as the third. Generative aperture on a level with the second pair of legs. Stigma comma-shaped; hypostome with three rows of teeth on each side. Palpi longer than hypostome. Size, 5 by 2·5 millimetres.

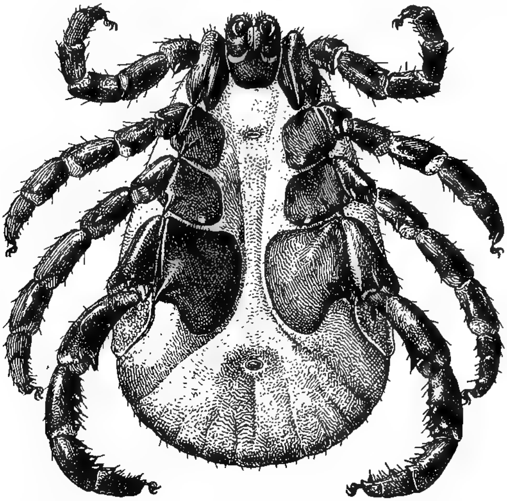

FIG. 199.—DERMACENTOR OCCIDENTALIS (MALE): VENTRAL ASPECT.

Young female: Oval depressed body, broader posteriorly than anteriorly; reddish-brown in colour; about the same size as the male—5 by 2·5 millimetres. Scutum very large, and marked like the anterior part of the male, extending as far back as the third pair of legs, with eyes in the anterior part of the lateral border. Dorsal surface of abdomen with a marginal groove beginning behind the eyes, and three longitudinal grooves running backwards, the two lateral beginning just behind the scutum, and the median about the centre of the body. Posterior margin with eleven festoons. Ventral surface with fine hairs. Genital aperture at the level of the second coxa; genital grooves close together at first, but diverging laterally behind the fourth coxa, and ending between the second and third external

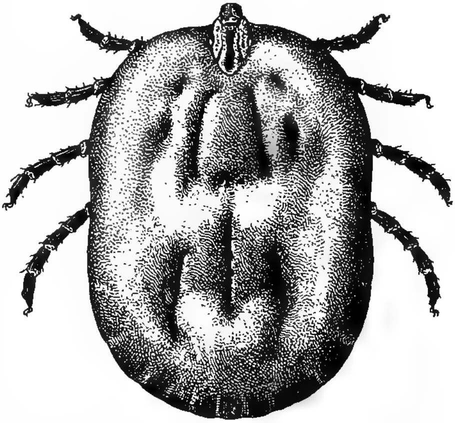

FIG. 200.—DERMACENTOR OCCIDENTALIS (REPLETE FEMALE): DORSAL ASPECT.

festoons. Anus with short anomarginal groove. Stigma comma-shaped.

Capitulum with the posterior lateral angle prolonged into a sharp point. Porose areas circular. Internal apophysis of the mandible with strong posterior tooth; external with three successive teeth. First coxa bidentate, other three with spines.

Replete Female: Swollen body laterally constricted at the stigmata; of deep brown or slate colour; size, 16 by 10 millimetres.

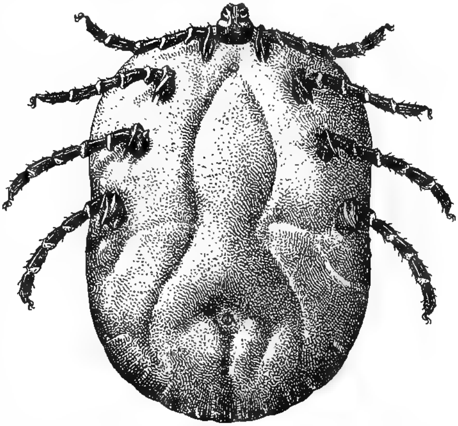

Fig. 201.—Dermacentor occidentalis (Replete Female): Ventral Aspect.

Life-History.—The egg hatches in seven to ten days, and produces a larva which feeds on some animal for several days, and then, becoming swollen and of a uniform slate-colour, drops off, and becoming quiescent, moults and gives rise to the nymph. This nymph again attacks an animal, and when fed drops off, and in ten days moults and becomes the adult. The nymph, however, can hibernate. If the adults do not obtain a host, they die off quickly.

Pathogenesis.—It is the spreader of Rocky Mountain fever.

· **Hæmaphysalis** Koch 1844 (*vide* Figs. 190-193).

Rhipicephalinæ without eyes, with the base of the capitulum rectangular; twice as broad as long. Palpi triangular or crescentic. Stigmata circular or comma-shaped. Anal shields absent. Tegument brownish.

Type.—*H. concinna* Koch 1844.

Species.—*H. concinna, H. leachi, H. flavii, H. punctata,* the life-history of the last named having been studied in detail by Nuttall, Cooper, and Robinson.

Hæmaphysalis leachi Audouin 1827.

This species is found in Africa, Sumatra, and New South Wales. It is the South African dog tick.

The male is 3 by 1·5 millimetres, with yellowish-red scutum, finely punctated dorsum, with eleven marginal festoons. Palpi longer than hypostome. Coxæ of all legs, with a short spine.

The female is 9 by 5 millimetres; scutum oval, larger than wide. Second segment of palpi long and spiny.

Life-History.—The larva, after feeding, drops off the dog, and moults. The nymph attacks another dog, feeds, drops off, and moults. The adult attacks a third dog, feeds, drops off, and lays eggs which develop larvæ.

Pathogenesis.—It is the spreader of *Babesia canis* among dogs, causing their biliary fever. Nuttall and Hadwen have shown that this canine babesiasis can be successfully treated by hypodermic injections of 6 c.c. of a 1 per cent. solution of trypanrot, or 4·5 to 5·5 c.c. of a saturated solution of trypanblau.

SUBFAMILY IXODINÆ.

The following diagnostic table, modified slightly from Salmon and Stiles, will indicate the genera :

A. Eyes absent :
  I. Pre-anal crescentic groove opens posteriorly :
    (*a*) Palpi valvate—*Ixodes.*
    (*b*) Palpi clavate—*Eshatocephalus.*
  II. Post-anal crescentic groove open anteriorly—*Aponomma.*
  III. Without anal groove in the female ; one anal shield in the male—*Ceratixodes.*
B. Eyes present :
  I. Anal plates absent—*Amblyomma.*
  II. Anal plates present on males—*Hyalomma.*

Ixodes Latreille 1796.

Synonyms.—*Cynorhæstes* Hermann 1804, *Crotonus* Dumeril 1822.

Ixodinæ without eyes, and with long palpi hollowed on the internal surface. Tarsi without terminal spurs. Pre-anal groove open posteriorly.

Male with scutum not covering the lateral and posterior margins ; no festoons ; stigmata oval. Ventral shields six in number ; two lateral surrounding the coxæ and stigmata, one median between genital pore and anus, and two adanal.

Female with three dorsal longitudinal grooves and two longitudinal genital ventral grooves, and the anal crescentic groove already mentioned.

Type.—*Ixodes ricinus* Linnæus.

Ixodes ricinus Linnæus 1758.

Synonyms.—*Acarus reduvius* Linnæus 1758, *A. ricinus* Linnæus 1758.

This is the castor-oil tick, and is found in Europe, North Africa, and North America on man, sheep, goats, cattle, horses, dogs, cats, rabbits, bats, birds, etc.

The male has an oval body, broader posteriorly, 2·5 by 1·5 millimetres. Scutum convex, deep red-brown. Genital pore on a plane with the third coxa. Pregenital and anal shields well marked. Capitulum long.

The female, when young, has flat, oval body. Pregnant and replete female is like a castor-oil bean, 10 to 11 by 6 to 7 millimetres, of ashy colour. Tegument covered with fine, short hairs. Dorsal surface with three well-marked posterior grooves and two anterior.

Genital pore at the level of the fourth coxæ. Genital grooves unite in front of the vulva.

Well-marked pre-anal crescentic groove, open posteriorly. Stigmata whitish. Porose areas elongated transversely. Mandibles with two teeth on the internal apophysis, and external with five teeth.

Life-History.—The female lays about 1,000 eggs in about one to two weeks, which take six weeks to hatch into a larva, which remains one week on the first host, and then four weeks on the earth before it becomes a nymph. This stage requires one week on the second host and eight weeks on the earth before it becomes the adult, which seeks the third host, copulates, sucks blood, and drops off to lay eggs.

Pathogenesis.—It acquires *Babesia bigeminum* from infected cattle in the adult stage, and spreads it to fresh cattle in the larval and nymphal stages.

Ixodes hexagonus Leach 1815.

Synonyms.—*Ixodes autumnalis* Leach 1815, *I. erina* Audouin 1832, *I. reduvius* Audouin 1832, *I. sexpunctatus* Koch 18 .

This is the European dog tick, and is non-pathogenic.

Eschatocephalus Frauenfeld 1853.

Synonyms.—*Sarconissus* Kolenati 1857, *Hæmalastor* Koch 1857.

Ixodinæ without eyes, and with a long rostrum. Palpi pyriform in the male and claviform in the female. Pre-anal groove opening posteriorly. Stigmata circular. Legs long.

Male with dorsal and ventral irregular chitinous thickenings.

Female with very fine parallel grooves.

Type.—*E. vespertilionis.*

There are over seven species found in bats and in caves.

Aponomma Neumann 1899.

Synonym.—*Ophiodes.*

Ixodinæ without eyes, and with the base of capitulum usually pentagonal, with dorso-lateral border very short; palpi long. Post-anal groove. Ventral sexual grooves.

Male nearly as broad as long, with a scutum marked with green spots covering the whole dorsal surface.

Female scutum shorter than broad.

Type.—*A. gervaisi.*

These ticks are found on reptiles.

Ceratixodes Neumann 1904.

Ixodinæ with long palpi, without eyes, and without anal groove in female. Stigmata circular. One anal and two adanal shields in the male.

C. putus is the only known species, and lives on sea-birds, and is found on cliffs.

Amblyomma Koch 1844.

Ixodinæ with flat eyes ; rostrum long, with valvate palpi. Anal groove semicircular, opening anteriorly. No median ano-marginal groove ; no anal plates in the male. Stigmata triangular. Nearly always eleven festoons.

Type.—*A. cajennense.*

Amblyomma hebræum Koch.

This tick is found in Africa, especially in Cape Colony, where it is called the ‘ bont,’ or variegated tick, and is the spreader of ‘ heart-water ’ in sheep and goats.

Morphology.—Male with white scutum, variegated with brown, and finely punctated and marked with longitudinal grooves. Marginal festoons green, except the two outer, which are brown. Female with brown or white scutum, as broad as long ; body 24 by 15 millimetres.

Life-History.—The usual life-history for Ixodidæ.

Pathogenesis.—Transmits ‘ heart-water ’ in sheep.

Hyalomma Koch 1844.

Ixodinæ with eyes, rostrum long, palpi valvate, anal groove semicircular, opening forwards, uniting sexual grooves, and followed by a median ano-marginal groove. Male with two pairs of ventral shields, two adanal and two lateral. Female with triangular stigmata.

Type.—*Hyalomma ægyptum.*

Only a few species : *H. ægyptum*, *H. crassitarsus*, *H. affine*, *H. syriacum*, *H. rhipicephaloides*, *H. hippopotamense.*

Hyalomma ægyptum Linnæus 1758.

Synonyms.—*Acarus ægyptus* L. 1758, *Ixodes camelinus* Fischer 1823.

This tick is found in Africa, particularly in Egypt and South Africa ; in Asia, particularly in Southern India ; in Europe, especially in France and Italy. The adults attack cattle, especially sheep and goats, and also at times man. The larvæ and nymphæ are supposed to attack birds, not cattle.

The male is almost black, with a pale marginal stripe, with a small, triangular, often white, median festoon.

The female is brown, with light blue stripes. Scutum, which as a rule is as broad as long, possesses numerous punctations, and is indentated behind the eyes.

Life-History.—This appears to require further investigation.

Pathogenesis.—Nil.

SUBORDER IV. PROSTIGMATA.

The suborder Prostigmata contains two superfamilies, which are of importance in medicine.

SUPERFAMILY A. TROMBIDOIDEA.—Prostigmata in which the last joint of the palpi is bent down towards the penultimate joint, which usually ends in a claw. Body often with many hairs.

SUPERFAMILY B. EUPOPOIDEA.—Prostigmata with simple palpi, in which the last joint of the palpi is not bent down towards the penultimate joint. Body with few hairs.

SUPERFAMILY A. TROMBIDOIDEA.

The Trombidoidea include the following families, which are of importance in medicine: (1) Trombididæ; (2) Tetrarhynchidæ; (3) Cheyletidæ.

1. TROMBIDIDÆ.

Trombidoidea with soft skins, and chelate mandibles adapted for biting.

The larvæ of this family are the harvest-mites, and are widely distributed; *Leptus autumnalis* Shaw 1790 being the harvest-bug, which is not uncommon in South England in August and September, and also in the South of France and Germany, where it principally attacks small mammals, dogs, and cats, from which they are supposed to pass to man. *Leptus americanus* Riley and *L. irritans* Riley are American species, being found in the United States and Mexico. *Trombidium tlalsahuate* Lemaire 1867 is the *Tlalsahuate* of Mexico. The zoological names of the ‘ pou d'agonti ’ of Guiana, the ‘ niaibi ’ of New Granada, the ‘ colorado ’ of Cuba, the ‘ mouqui ’ of Para, the ‘ bête rouge ’ of Martinique and Honduras, are not known. It must be confessed that there is a great deal of uncertainty about the genus and species of these larvæ, and the subject evidently requires revision. It is apparently by no means certain what is the adult of *L. autumnalis*.

Morphology.—They are six-legged larvæ with prominent claws on the tips of their legs, provided with a powerful hypostome, which they drive through the skin. Around this hypostome the tissues of the host are supposed to form a tube.

Life-History.—Only the larvæ appear to be parasitic; the adults apparently are not. The life-history has not been fully traced out, and though it is often stated that *L. autumnalis* is the larva of *Trombidium holosericeum*, this is by no means certain.

Pathogenesis.—They cause itching, redness, and swelling of the affected part, which, if scratched, may become eczematous, and even at times suppurate.

Treatment.—Sulphur ointment kills them.

Akamushi, or Kedani.—Under this term comes the larval mite which causes tsutsugamushi, or Japanese river fever. It is orange-red in colour, 0·16 to 0·38 millimetre in length by 0·10 to 0·24 millimetre in breadth. The palpi are leg-like, and the body has many long hairs, while the legs are very hirsute. The life-history appears to be unknown.

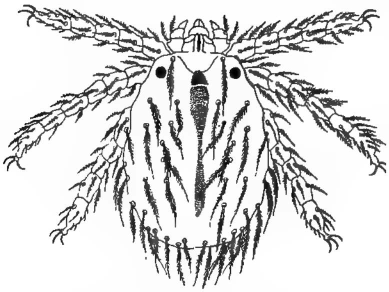

FIG. 202.—AKAMUSHI.
(After Tanaka, from *Centralb. für Bakteriologie Par. und Inf.*)

2. TETRANYCHIDÆ.

Trombidoidea with first and second pairs of legs without spines; skin with few shields; palpi not much thickened on base, moving vertically; eyes usually present. First pair of legs do not end in long hairs. Coxæ more or less in two groups. Body with fewer longer hairs. No dorsal groove; often spinning threads; tarsi never swollen. Mandibles styliform.

Tetranychus molestissimus Weyenbergh 1886.

This mite is found in the Argentine and Uruguay. It is small and of red colour, living in a web on the inferior surface of the leaves of *Xanthum macrocarpum.* From December to February it attacks mammals and man, thrusting its hypostome into the skin, and causing severe itching. Another species—*T. telarius* (var. *russeolus*) L. 1758—may attack human beings.

3. CHEYLETIDÆ.

Trombidoidea without spinous processes on the legs; skin with few, if any, shields; palpi much thickened at the base, moving laterally; last joint often with two pectinate bristles without eyes. First leg ending in several long hairs.

These are very small mites, distinguished by having enormous palpi. *Cheyletus mericourti* Laboulbène has been described by Theobald in the ear of a human being.

SUPERFAMILY B. EUPOPOIDEA.

FAMILY 1. EUPOPIDÆ.

Eupopoidea with palpi not geniculate, and unable to grasp prey. Beak small; last joint of the first leg shorter, or but little larger, than preceding joint.

Tydeus molestus Moniez 1889.

This mite was imported into Belgium in Peruvian guano, and caused much trouble to man and beast.

FAMILY 2. TARSONEMIDÆ.

With marked sexual dimorphism and tracheæ. No ventral suckers.

Pediculoides ventricosus Newport 1850.

Synonyms.—*Heteropus ventricosus* Newport 1850, *Acarus tritici* Lagrèze-Fossot 1851, *Physogaster larvarum* Lichtenstein 1868, *Sphærogyna ventricosa* Laboulbène and Mégnin 1885.

This mite causes severe itching and urticarial eruptions on the breast, arms, face, neck, and shoulders of persons handling corn and barley, which contains it in India, Algeria, and Europe.

Morphology.—Males are oval, 0·12 by 0·08 millimetre, with six pairs of dorsal hairs and a lyre-shaped lamella.

Female cylindrical, 0·2 by 0·07 millimetre; becomes much distended posteriorly when gravid.

Life-History.—They live on the stalks of cereals, and feed on animal and vegetal juices. The adult hatches directly from the egg.

Pathogenesis.—They cause diffuse erythema, urticaria, and itching.

Other Species.—*Chrithoptes monunguiculosus*, *Tarsonemus uncinatus*, *T. intectus*.

SUBORDER V. ASTIGMATA.

This suborder includes the superfamily Sarcoptoidea.

SARCOPTOIDEA.

Astigmata with small, three-pointed palpi adhering for some distance to the hypostome, with usually ventral suckers.

Among the families of the Sarcoptoidea there are two which concern us—(1) Tyroglyphidæ, (2) Sarcoptidæ.

1. TYROGLYPHIDÆ.

Very small mites without eyes; only accidental parasites being found in flour, sugar, cheese, etc.

Tyroglyphus.—With smooth dorsum, with claws and suckers. *T. farinæ* (De Geer) in corn may get into the skin. They are the cause of so-called vanillismus. According to Theobald, Linnæus reported a case of dysentery as being due to this species (*Acarus dysenteriæ*).

Glyciphagus.—With dorsum covered with hairs.

G. prunorum Hermann and *G. domesticus* de Geer are the cause of grocer's itch.

Rhizoglyphus parasiticus Dalgetty 1901.—With short legs, armed with spines. Tarsi end in a claw. Live on plants.

This is the species which causes trouble in the feet of Indian coolies. Bell describes a large circular, superficial sore on the sole of the foot, caused by many of these parasites invading the skin.

Histiogaster spermaticus Trouessart 1900.—This mite, which feeds on vegetables, appears to have been introduced into a patient by means of a catheter, and to have formed a cyst in the testis in a man in India.

2. SARCOPTIDÆ.

Sarcoptoidea without genital suckers, without clinging apparatus, with transverse vulva. Lines in skin.

Sarcoptes Latreille.—Sarcoptidæ with round or slightly oval bodies; posterior two pairs of legs concealed beneath the body; tarsi end in simple long pedicles with ambulatory suckers.

Sarcoptes scabiei, var. hominis.—Female lives in furrows in the epidermis, in which it lays its eggs. Posterior legs end in spines. Males occur on the surface and die after copulation. Posterior legs end in suckers. Six-legged larva hatches in four to eight days.

Sarcoptes minor Fürstenberg 1861.—Usually a parasite of cats; has been found on man.

Nephrophages sanguinarius Miyake and Scriba 1893.—Is a very doubtful parasite of man.

Sarcoptidæ as internal parasites.—Sarcoptidæ have been described by Newstead and Todd as internal parasites in monkeys. An Acarid-like parasite was found by Castellani in the omentum of a negro in Uganda. This parasite somewhat resembled *Cytoleichus sarcoptoides* Heguin, which lives in the air sacs, and at times the liver and kidneys of fowls.

SUBORDER VI. VERMIFORMIA.

Very minute Acarina, with abdomen elongated and annulated, without tracheæ, and with epimeres on the legs.

This suborder contains only one family.

FAMILY DEMODICIDÆ.

Vermiformia with eight legs, living on animals.

This family includes only one genus—*Demodex*.

Demodex.

With the family characters.

The species of *Demodex* lives in the sebaceous glands and hair-follicles of mammals and man. The mouth consists of a rostrum, which is arranged for sucking. The palpi are three-jointed, and pressed to the under surface of the rostrum. The legs are eight in number, short, and consist of three segments, with small terminal ungues. The abdomen is tapering, striated dorsally and ventrally, and rounded at the tip. The anus is situated at the anterior end of the abdomen.

Demodex folliculorum Simon 1842.

Synonyms.—*Acarus folliculorum* Simon 1842, *D. folliculorum* Owen 1843, *Macrogaster platypus* Miescher 1843, *Simonea folliculorum* P. Gervais 1844, *Stealozoon folliculorum* Wilson 1847.

This parasite was first discovered by G. Simon, of Berlin, in 1842, in the contents of pustules of *Acnea sebacea*.

About the same time Henle had found them in hair-follicles in the external auditory meatus, and Topping a variety in the dog. Two other species are known: *D. phylloides* Cook in pigs and *D. bovis* Stiles in cattle. *D. folliculorum hominis* is cosmopolitan, living in the sebaceous follicles of the face.

Male measures 300 μ by 40 μ, and the female 380 μ by 45 μ.

Life-History.—The eggs are 60 to 90 μ in length by 20 to 50 μ in breadth, and heart-shaped or fusiform. The egg hatches out a six-legged larva, which develops into an eight-legged nymph, from which the adult appears.

Pathogenesis.—Usually said to be nil, but Borrel considers them to play a part in the spread of cancer and leprosy.

ARACHNIDÆ INCERTÆ SEDIS.

LINGUATULIDA.

Parasitic Arachnoidea with ringed, elongated, vermiform bodies, possessing two pairs of hooks in the neighbourhood of the jawless mouth.

The *Linguatulida* have been found parasitic in man both in the adult and larval conditions, but the adult is much rarer than the larva. They have been found in Europe and Africa, and reported from the West Indies, but this was in a negro from West Africa. It is not impossible that they will be found to be far from uncommon parasites when the medical history of the West Coast of Africa is better known. When dealing with cases showing obscure abdominal or pulmonary symptoms in that part of the world, the medical man should remember these parasites.

Morphology.—The body is white in colour and vermiform in appearance, and, indeed, they were long mistaken for worms.

It is elongated, flattened, or cylindrical, and marked by a variable number of rings, and is usually divisible into two regions—an anterior broader portion called the cephalothorax, and a posterior, more attenuated, called the abdomen. It is covered with a chitinous cuticle pierced by pores, called stigmata, which have nothing to do with respiration, being merely the orifices of epidermal glands.

The mouth is situated anteriorly, and is either terminal or subterminal, with a chitinous ring. Two pairs of chitinous hooks, retractile into grooves, are situate on either side of the mouth, and are looked upon by Stiles as antennæ and palpi. There are no legs. The anus is terminal at the posterior end of the abdomen, with the female aperture situate just in front. The male generative pore is on the ventral surface, near the anterior end of the abdomen. The sexes are distinct. The mouth leads into a simple straight alimentary canal, which ends in the anus. There are no circulatory or respiratory organs. The nervous system consists of a ventral mass and a circumœsophageal commissure.

Life-History.—The female produces eggs, which, escaping from the definitive host, pass into the intermediary host, and there hatch out a four-legged larva, not unlike an embryo *Acarus*. This embryo undergoes complete metamorphosis, and forms a nymph, resembling the adult, which does not, as a rule, mature until it reaches its definitive host again.

Genera.—*Linguatula*, *Porocephalus*.

Linguatula Fröhlich 1789.

Linguatulida with depressed body, rounded dorsum, and crenate margins. Body cavity forming diverticuli into the lateral parts of the rings.

Species.—*Linguatula serrata*.

Linguatula serrata Frölich 1789.

Synonyms.—*Tænia rhinaria* Pilger 1802, *Polystoma tænioides* Rudolphi 1810, *Linguatula tænioides* Lambinet 1816, *Pentastoma tænioides* Rudolphi 1819.

Larval Synonym.—*Pentastoma denticulatum*.

The adult lives in the nasal cavity and frontal sinus of the dog, wolf, fox, and rarely in the horse, mule, sheep, goat, and man in Europe; while the larva exists in sheep, oxen, horses, rarely in cats and dogs. Its real host appears to be the dog, especially sheep-dogs.

Habitat.—Europe, especially Central France.

Morphology.—The male is white in colour, 18 to 20 millimetres in length, and 3 millimetres broad. The female is greyish-white or brownish, owing to the contained ova.

Life-History.—The eggs, which are ovoid, 90 by 70 μ, are laid in the nasal cavities of the dog, and expelled by sneezing. If they fall on grass, they may enter the alimentary canal of a herbivorous animal, in whose intestine the embryo hatches. This embryo measures 130 by 60 μ, and possesses two pairs of legs and an anterior perforating apparatus composed of a stylet and two hooks.

It now bores its way into the liver, lungs, or some other organ, and in about eight weeks becomes encysted, losing all its appendages and measuring 275 by 180 μ.

A succession of ecdyses results in the formation of the nympha, which resembles the adult, except that it possesses numerous chitinous spicules on its skin, and by the sixth to the seventh month is about 6 to 8 millimetres in length.

These nymphæ now wander about the host, and are supposed to reach the bronchi, and thus to leave the herbivorous host and reach the dog either by the nose or mouth, in the nasal cavities of which they moult and become sexually mature, copulating about the sixth to seventh week after infection.

Both the larva and the adult may be found in man, the former in the lung, rarely in the liver, spleen, or intestinal wall. The latter has but rarely been met with, and then appears to be due to embryos wandering into the nose and developing directly. It has only been so far found in Europe.

Porocephalus Humboldt 1811.

Linguatulida with cylindrical body and continuous cœlom.

Porocephalus armillatus Wyman 1848.

Synonyms—*Adult.*—*Linguatulida armillatus* Wyman, *Pentastomum polyzonum* Harley. *Larva.*—*Pentastomum diesingi* Beneden, *P. euryzonum* Diesing, *P. leonis* Weddell, *P. constrictum* von Siebold, *P. protelis* Hoyle, *Linguatulida constrictus* Bruner.

Porocephalus with cylindrical body, slightly flattened on its anterior face, and surrounded by about sixteen to twenty-two distinct rings, separated from one another by a wide interval. The body tapers from the middle backwards.

The larva of this parasite was discovered by Pruner in the liver of two negroes in Cairo in 1847, and subsequently by Bilharz, Fenger, Kearney, Crawford, Marchoux, Chalmers, and others; while the adult was discovered by Wyman in 1848 in the lungs of the African python. Sambon has recently studied both adult and larva.

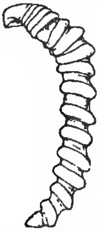

FIG. 203.—POROCEPHALUS ARMILLATUS WYMAN (MALE): NATURAL SIZE.

(After Sambon.)

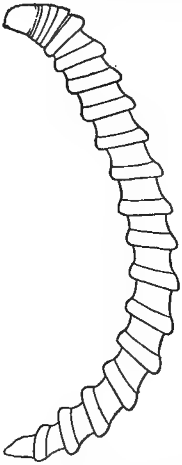

FIG. 204.—POROCEPHALUS ARMILLATUS W. (FEMALE): NATURAL SIZE.

(After Sambon.)

The adult lives in African pythons and snakes (*Python sebæ*, *P. regius*, *Bitis nasicornis*, and *B. arietans*). The larval forms usually occur in *Proteles cristatus*, *Cynocephalus maimon*, and other monkeys; in *Erinaceus æthiopicus*, the African hedgehog; and in *Felis leo*, the lion.

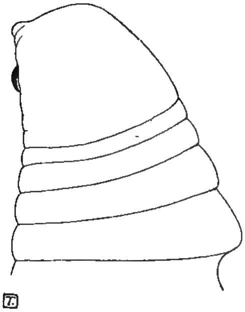

FIG. 205.—LATERAL ASPECT OF THE CEPHALO-THORAX OF POROCEPHALUS ARMILLATUS W. (× 5).

(After Sambon.)

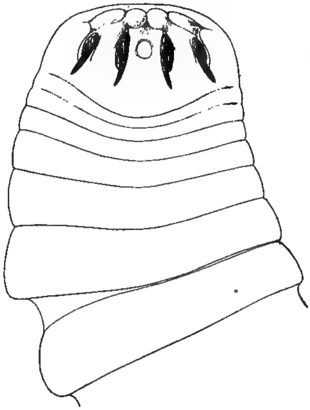

FIG. 206.—VENTRAL ASPECT OF THE CEPHALO-THORAX OF POROCEPHALUS ARMILLATUS W. (× 5).

(After Sambon.)

Morphology.—Female 9 to 12 centimetres in length and 5 to 9 millimetres in breadth, with eighteen to twenty-two rings, each 1 to 2 millimetres in width. The cephalothorax extends from the anterior end of the body to the first body-ring, which is often very indistinct. Dorsally this region is convex, while ventrally it is concave, and carries the mouth, in front of which there are two papillæ, and on either side of which there are two hooks. Genital opening about 1 millimetre in front of the anus, which is terminal. Male 3 to 4·5 centimetres in length and 3 to 4 millimetres in breadth,

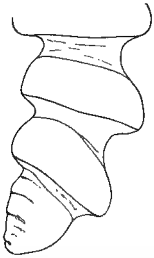

FIG. 207.—POSTERIOR END OF POROCEPHALUS ARMILLATUS WYMAN (× 5).

(After Sambon.)

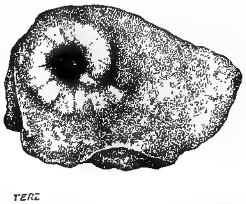

FIG. 208.—NYMPH OF POROCEPHALUS ARMILLATUS WYMAN ENCYSTED IN THE LIVER.

(After Sambon.)

with sixteen to seventeen rings. Genital opening in the middle of the ventral surface at the anterior end of the abdomen.

Life-History.—Probably this resembles that of *Linguatula serrata*, with the difference of hosts. In man the nymphæ are found not merely encysted in the lungs and liver, but moving free through the peritoneal cavity and in the small intestine. Sambon considers that the eggs pass from the snake into water, and thence into animals and man while drinking, and become larvæ and nymphæ, which latter gain access to the snake when the host is killed and eaten.

Pathogenesis.—This will be described later (Chapter XXXIV.).

Porocephalus moniliformis Diesing 1836.

Porocephalus with twenty-eight to thirty rings.

The larvæ of this species are reported by Salm as being found in the small intestine of a Djambi native in Java. The adults occur, in snakes.

CLASS IV. CRUSTACEA LAMARCK 1815.

Aquatic Arthropoda which breathe by means of gills.

Crustaceans can hardly be considered as human parasites, for they have very rarely occurred as such—*e.g.*, *Caligus curtus* in the cornea, and *Gammarus pulex* in the stomach.

It must, however, be remembered that the Copepoda are of importance, because a species of *Cyclops* has been found to be the intermediary hosts of *Filaria medinensis*, the guinea-worm. An excellent paper on the species found on the Gold Coast is contributed by Graham to vol. i. of the *Annals of Tropical Medicine and Parasitology.*

CLASS V. CHILOPODA.

Arthropoda with three prosthomeres. The first post-oral somite is the mandibular; the second and third post-oral somites carry the maxillæ, while the fourth has its appendages converted into very large powerful jaws, which are provided with poison glands. The remaining somites carry single-clawed walking-legs, one pair to each somite. Body anomomeristic, showing from 17 to 175 somites behind that which carries the poison glands. They breathe by tracheæ, and the genital ducts open on the penultimate somites.

Family 1. Scolopendridæ.
Family 2. Lithobiidæ.
Family 3. Scutigeridæ.

1. SCOLOPENDRIDÆ.

Chilopoda with antennæ, possessing few joints, and with few ocelli.

Geophilus carpophagus Leach, *G. electricus* Linnæus, *G. cephalicus* Wood, *G. similis* Leach, have been found as accidental parasites about nineteen times in the nasal cavities and their neighbouring sinuses in man in Europe. *G. electricus* Linnæus has been found in the alimentary canal about four times.

2. LITHOBIIDÆ.

Chilopoda with many-jointed antennæ; numerous ocelli.

Lithobius fortificatus L. and *L. melanops* have been found in the nasal cavities in three cases in man.

3. SCUTIGERIDÆ.

Chilopoda with antennæ at least as long as the body, and faceted eyes instead of ocelli.

Scutigera coleoptrata has been found in the alimentary canal.

Other species found in the alimentary canal are: *Chætechelyne vesuviana* Newport, *Himantarium gervaisi*, *Stigmatogaster subterraneus*.

Pathogenesis.—In the nose these parasites cause inflammation with, at times, no flow of mucus, and at others a large discharge of it, associated with headache, which is generally more or less continuous, but may show remissions. In addition to these local symptoms, general symptoms such as convulsions, anginiform attacks, dyspnœa, etc., may be induced through irritation of the fifth nerve. There is no evidence that these parasites cause any of the symptoms by their venom. They are generally expelled in attacks of sneezing or spontaneously. The best methods of making them leave the nostrils are applications of snuff, eau de Cologne, or turpentine; but in some instances it will be necessary to open a sinus—*e.g.*, the frontal sinus—by surgical means in order to remove the parasite.

In the alimentary canal the symptoms will give rise to the suspicion of helminthiasis. They are: pain in the abdomen, cramps, nausea, vomiting, and reflex nervous symptoms.

Treatment does not appear very satisfactory.

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CHAPTER XVIII

BIOLOGICAL CAUSES OF DISEASE (*continued*) —THE HEXAPODA

Hexapoda—Siphunculata—Pediculidæ—Ricinidæ—Hemiptera—Cimicidæ—Reduviidæ—Lygæidæ—References.

CLASS HEXAPODA.

Synonym—*Insecta.*—Arthropoda breathing by means of tracheæ, with antennæ on the head, three pairs of legs, and usually two pairs of wings on the thorax, which is composed of three segments. Abdomen with generally nine apparent segments.

The Hexapoda, or insects, have recently become known to be of the utmost importance in the spread of disease, for the researches of Manson, Ross, Grassi, and others have shown that they can spread the parasites of filariasis, malaria, and other diseases.

Morphology.—The body is distinctly divided into head, thorax, and abdomen. The head is composed of the fusion of about six segments, which are the ocular, antennal, intercalary (probably homologous with the second antennal segment of the Crustacea), mandibular, maxillary, and labial; but whether the hypopharynx represents a seventh segment or not is doubtful. The head carries, in addition to the eyes, four pairs of appendages, one for each somite or segment, except the intercalary segment, which is premandibular. These appendages are the antennæ, the mandibles, the maxillæ to which are attached palpi called the maxillary palps, and a second pair of maxillæ usually fused to form the lower lip or labium, which generally carries a pair of labial palps.

The exoskeleton of the head is composed of sclerites—that is to say, more densely chitinized regions of the integument—which are: (1) The clypeus; (2) the epicranium; (3) the gula.

The clypeus is the sclerite situate on the anterior portion of the dorsal surface, and carrying the labrum; in flies it is often called the face.

The epicranium is the larger part of the head, and may be subdivided into an anterior frons and a posterior occiput. The genæ form the sides of the head, meeting the epicranium and the gula at the occipital foramen.

The gula is the sclerite in the median ventral line which carries the basal part of the labium called the submentum. There is no exoskeleton at the posterior part of the head ventral to the occipital region, which thus forms a foramen in the hard tissues called the occipital foramen, through which the soft structures of the head communicate with those of the thorax.

The antennæ appear to be sensory organs, and the mandibles to vary in structure according as to whether the mouth is to be used for biting or sucking. In the former case they are broad and strong, while in the latter they are styliform. The first pair of maxillæ, similarly, may be broad, strong organs or styliform organs.

In addition to these appendages, the mouth shows an upper lip or labrum, which is simply a sclerite attached to the cephalic shield, and may have a median projection from its internal surface called the epipharynx, while the labium has a similar one called the hypopharynx. Thus the mouth parts of an insect may be very complicated, with labrum and epipharynx, mandibles, maxillæ, and maxillary palps, labium, and hypopharynx.

The thorax is joined to the head by a neck, and is subdivided into three segments—prothorax, mesothorax, and metathorax. These somites are by no means simple horny rings, but have their chitinous exoskeleton split up into hard pieces joined together by soft material. The hard pieces are a dorsal plate called 'the notum,' a ventral plate called 'the sternum,' and lateral plates called 'pleura.' Further, the terms 'pro,' 'meso,' and 'meta,' are applied to these, indicating the region to which they belong—'pronotum,' 'mesonotum,' and 'metanotum'; 'pro-,' 'meso-,' and 'metasternum'—while each pleuron is divided into an anterior episternum and a posterior epimeron. According to Audouin, a typical thoracic segment should have a notum composed of præscutum, scutum, scutellum, and post-scutellum, but all these parts are seldom seen.

Each somite of the thorax carries a pair of jointed walking-legs, in which the segments or articles are named coxa, trochanter, femur, tibia, metatarsus, and tarsus (consisting of several joints), terminated by claws or ungues, between which other appendages called empodia and pulvilli are to be found, as will be explained later.

Typically, the mesothorax and the metathorax should each carry a pair of wings, which are transparent and strengthened by nervures, ribs, or veins, which are chitinous canals containing blood spaces, nerves, and tracheæ. The areas between the nervures are called cells. The wings, however, become much modified in the different orders, and may be entirely absent. The arrangement of the nervures in the wing is called the 'venation,' and has been restudied by Comstock and Needham, who find that the primitive type is composed of two main tracheal branches, an anterior and a posterior. The anterior breaks up at the base of the wing into four longitudinal branches—the costa, subcosta, radius, and media—while the posterior has also four branches, of which the first is called the cubitus, and may be subdivided into two; and the other three are simple, and are called the anal veins—first, second, and third. The costal vein is unbranched, and runs along the anterior margin of the wing. The subcostal vein typically divides into two branches, the radial vein into five branches, and the median into four.

This primitive type is altered by atrophy or coalescence, leading to the reduction of the veins. The latter may take place from the base towards the tip, or from the tip towards the base of the wing, called outward and inward coalescence respectively. The wing cells may be named as follows:

1. Costal Cell, between the Costa and the Subcosta.
2. Mediastinal, between the Subcosta and the Radius.
3. Marginal, between Radius 1 and Radius 2.
4. First Submarginal, between Radius 2 and Radius 3.
5. Second Submarginal, between Radius 3 and Radius 4.
6. Third Submarginal, between Radius 4 and Radius 5.
7. First Posterior, between Radius 5 and Media 1.
8. Second Posterior, between Media 1 and Media 2.
9. Third Posterior, between Media 2 and Media 3.
10. Fourth Posterior, between Media 3 and Media 4.
11. Fifth Posterior, between Media 4 and Media 5.
12. Sixth Posterior, between Media 5 and Cubitus 1.
13. Seventh Posterior, between Cubitus 1 and Cubitus 2.
14. First Anal, between Cubitus 2 and Anal 1.
15. Second Anal, between Anal 1 and Anal 2.
16. Axillary, between Anal 2 and Anal 3.
17. Spurious cell, behind Anal 3.

But all these cells are not present in any one given type of wing, owing to coalescence of the nervures, and hence the arrangement of the cells is different. Besides this, the venation is complicated by the presence of transverse veins, as will be explained in the next chapter.

The abdomen usually consists of ten somites, without appendages, composed of dorsal and ventral plates connected together and to preceding and succeeding segments by soft membranes. The posterior segments are often modified with reference to reproduction, possessing claspers in the male and ovipositors in the female. The anal opening is on the last abdominal segment, and the reproductive aperture on the penultimate segment.

Internal Anatomy.—The mouth lies between the labrum above and the labium below, and leads into an oral cavity.

The salivary glands in most of the genera which we have to consider are well developed, and are, as a rule, not connected with the mouth, but open into a common duct which communicates with a groove or canal on the hypopharynx, and so opens near the tip of the proboscis.

From the mouth a pharynx leads through an œsophagus, with a dilatation called the crop, into a proventriculus or masticatory stomach, which latter communicates with the mesenteron or chylific ventricle, whose juncture with the intestine is defined by the openings of the cæcal Malpighian tubules. This is an important landmark, defining where the stomach ends and the intestine begins. The intestine is subdivided into small intestine, colon or large intestine, and rectum. The last-mentioned may possess rectal glands, while anal glands may open into the rectum just in front of the anus, and are useful to the insect by forming the secretion which gives rise to repulsive odours.

With regard to the proventriculus, it should really be a powerful muscular organ lined with chitin, and possessing teeth, bristles, etc., but in the Diptera it will be found to be much degenerated. The Malpighian tubules, which number from four to six, are excretory in function. The alimentary canal possesses longitudinal and transverse muscular coats and a lining of epithelial cells.

The stigmata or openings of the respiratory system are situate on the membranes, on the side of the body, in the thorax and abdomen, and are very varied in number. They are never to be found on the head or on the last abdominal segment. From the stigmata the tracheæ, or air-tubes, ramify all over the body. These tracheæ are kept open by spiral thickenings of the chitinous lining membrane.

The fat bodies are lobulated masses packed beneath the skin and between the organs, and are supposed not merely to represent reserve material, but to be of great importance in metabolism.

The circulatory system consists of a dorsal longitudinal vessel divided into chambers, which pulsate, and an anterior aorta, from which blood flows freely into the cœlom or body cavity. From this it returns to the heart by two lateral vessels and one dorsal and one ventral vessel. The blood is colourless, and contains amœboid cells.

As already mentioned, some insects possess poison glands.

The nervous system and sense organs will not be described here, as they are not of importance in tropical medicine.

The male reproductive organs consist of testes, vasa deferentia, ductus ejaculatorius, and an external copulatory organ. The female reproductive organs are two ovaries, which consist of a series of egg-tubes, and oviducts which are united together to form the single oviduct, the lower portion of which is a vagina. This receives the cement glands and the sebaceous glands, which provide the secretion for glueing the eggs together and the receptaculum seminis, beneath which is the bursa copulatrix, which is sometimes separated from the vagina.

Life-History.—This is very varied. In general terms, the spermatozoa, bound into bundles of spermatophores, are introduced by the external copulatory organ, which, when protruded, is surrounded by the claspers in the form of a sheath, into the bursa copulatrix. The ovum, starting from the terminal portion of the ovarian tube, obtains, as it passes downwards, its food-yolk and its shell or membrane, the chorion, which has a small gap, the micropyle. On arrival at the junction of the oviduct and the spermatheca, or receptaculum seminis, the spermatozoa enter viâ the micropyle, and fertilize the egg. These eggs may be strung together as they are laid, into masses by means of the sebaceous secretion mentioned above. The egg may develop directly into the adult, but this is only in the lowest forms. Usually the egg develops into a larva, which becomes a nymph or pupa, and this into an adult, often called the 'imago.' This series of changes is called a metamorphosis. The pupa may present three forms:

1. *The free pupa*, with appendages free.
2. *The obtect pupa*, with appendages and body bound together.
3. *The coarctate pupa*, in which the pupa is contained in a puparium formed from the larval skin.

The larva is a most vigorous feeder, but the pupa does not take nourishment as a rule, though there are marked exceptions, especially among the Rhynchota and Siphunculata.

Habits.—We are mainly concerned with the predatory or blood-sucking insects. As a rule, the female only sucks blood, which, apparently, it does with a view of obtaining rich nourishment for its eggs. It is this habit which makes these insects of importance in tropical medicine, because not merely does it cause irritation by the introduction of secretions from the insects' salivary glands and mouth (alimentary canal), but also leads to the introduction into the victim of the germs of disease. Again, as we shall see later, larvæ are apt to become parasitic in man and animals, and in this way cause disease.

Enemies.—Insects and their larvæ have many enemies in birds, reptiles, fish, and other insects. Cannibalism is also met with, especially among mosquito larvæ.

Pathogenesis.—The principal disease-spreading insects are the Diptera; for example, the *Anophelinæ* disseminate malaria, the genus *Stegomyia* yellow fever, and the genus *Culex* filariasis, and perhaps dengue fever. The *Glossinæ* are responsible for human trypanosomiasis, while they and other flies spread the animal trypanosomiases.

In addition, the common house-fly is an important factor in the dissemination of typhoid and perhaps dysentery in tropical countries. Fleas are now known to be the spreaders of plague, and bugs perhaps of some of the relapsing fevers. This is a sufficient list of ills to commend insects and their habits to the serious notice of the medical practitioner of the tropics.

The Collection of Insects.—Mr. Austen, of the South Kensington Natural History Museum, has drawn our attention to the fact that though medical men throughout the tropics make collections of blood-sucking flies, they often mount them so badly that when they arrive in London they are quite useless for purposes of identification.

He has, further, asked us to invite the reader's attention to certain remark of his, taken from the second report of the Wellcome Research Laboratories which are as follows :

1. Specimens of blood-sucking and other Diptera intended for determination should be in *the most perfect possible condition.*
2. Specimens collected by *natives* seldom fulfil this condition.
3. Flies should, if possible, always be pinned, and should be drawn u *near the head of the pin,* and not left close to the point.
4. If pinning is impossible, specimens are best placed *in three-cornere envelopes* of soft paper.
5. Flies should *never* be placed in contact with *dry cotton-wool.*
6. *A plug of soft paper* must always be pressed down on top of specimen placed in spirit, in order to fix them in the tube.
7. Several specimens *of both sexes* should be sent if identification is desired
8. Specimens should always be *legibly labelled,* with the name of locality and date of capture, and notes of interest forwarded at the same time.

Classification.—The Hexapoda are classified into the followin orders, in accordance with Sharpe's arrangement, with the differenc that the lice are placed in a separate order :

1. Aptera.
2. Neuroptera.
3. Orthoptera.
4. Thysanoptera.
5. Hemiptera.
6. Siphunculata.
7. Diptera.
8. Lepidoptera.
9. Hymenoptera.
10. Coleoptera.

But the only orders which contain species important as spreader of disease or as human parasites are :

1. Siphunculata.
2. Hemiptera.
3. Diptera.
4. Coleoptera.

ORDER SIPHUNCULATA MEINERT 1891.

Hexapoda with labrum and labium joined together to form a rostrum o proboscis, which is armed with recurved hooklets, and contains a hollow extensile sucker formed by the mandibles and maxillæ. Eyes without facets. Antennæ five-jointed. Thorax with little traces of segmentation. Wings absent. Legs with hook-like terminal joints, suitable for clinging. Last abdominal segment rounded in male, notched in female. Metamorphosis incomplete.

The relationship of the Siphunculata to the Hemiptera was based upon the anatomy of the mouth, and is so doubtful that we have adopted Meinert's separate order.

The Siphunculata include the families (1) Pediculidæ, and (2) Ricinidæ.

FAMILY 1. PEDICULIDÆ.

Siphunculata with head narrower than the thorax.

Lice are found all over the world, on man as well as on animals. They cause much irritation by their bites, which may become infected, causing impetigo. Apart from this, however, they have recently been suspected of spreading blood-parasites—*e.g.*, *Trypanosoma lewisi* and *Hæmogregarina gerbilli*—which are believed to undergo development in them.

Morphology.—The head is usually clearly defined, but the thorax may or may not be so well defined from the abdomen. Eyes may be present or absent—a fact which appears to depend upon whether the host is nocturnal or not in its habits. The antennæ are usually five-jointed. The mouth consists of a proboscis, composed of labrum and labium, which is armed with recurved hook, and contains the maxillæ and mandibles, which take the form of a suctorial tube. The thoracic segments are fused together. The thorax may be as broad as the abdomen, or narrower. There are no wings. The legs have four segments, of which the terminal one carries a strongly curved claw. The abdomen has, if statements can be trusted, a various number of segments, differing in the different genera.

The last segment in the female has a slit-like opening guarded by two chitinous plates, while in the male there is in the same situation a horny papilla surrounded by spines.

Internal Anatomy.—Christophers and Newstead have recently studied the anatomy of *Hæmatopinus stephensi* Christophers and Newstead 1906, parasitic on *Gerbillus indicus* (the Indian field-rat).

The alimentary canal consists of a mouth followed by a chitinous pharyngeal pump, into which the ducts of the salivary glands open, and an œsophagus which leads into the mid-gut. This second part of the canal consists of two portions, of which the first appears to be a crop and the second a chylific ventricle. There are four Malpighian tubules. The intestine shows no differentiation into small and large. The rectum is globular, with a distended posterior portion containing the rectal papillæ. The fat-body is well developed. The female generative organs consist of two ovaries with oviducts. Each ovary consists of five to six follicular tubes. The two oviducts unite into a common duct, and there is a spermatheca. The male organs are testes, vasa deferentia, vesicula seminalis, and penis.

Life-History.—The ova, which are attached to the hairs of the host, give rise to larvæ, which closely resemble the adults.

Classification.—The Pediculidæ contain the lice which occur on man and animals alike, and cause much irritation. There are six genera and some forty species, but only the following need be described here:

Genera.—Pediculus, Phthirius, Hæmatopinus, which are distinguished as follows:

1. Thorax narrower than abdomen: (1) With distinct neck—*Pediculus*; (2) without distinct neck—*Hæmatopinus*.
2. Thorax broader than abdomen—*Phthirius*.

Pediculus.

Pediculidæ with five-jointed antennæ, distinct neck, thorax narrower than abdomen, and legs with a single terminal claw.

Pediculus humanus Linnæus 1758.

Synonyms.—*Pediculus capitis* de Geer 1778, *P. cervicalis* Latreille 1803.

This is the head-louse, which is cosmopolitan in distribution, but varies in colour on the different races, as was pointed out by Murray, being very dark on African negroes and Tamils, and said to be yellow on Chinese and Japanese, and orange on Hottentots.

In Europeans it is light grey in colour. Daniels says that the pediculi of Chinese do not pass readily to Tamils; though in our experience the pediculi of native servants, Sinhalese and Tamils, will pass to Europeans.

These pediculi are extremely common in the tropics, and it is an everyday scene to witness natives busy at work killing them on their friends' heads.

Morphology.—The head-louse is about 2 millimetres in length by 1 millimetre in breadth. The female is larger than the male, and exists in greater numbers. The head is triangular, the thorax broad with short legs, and the margins of the abdomen are dark.

Male.—The posterior somite is rounded off and prominent, with a circular opening dorsally, which is the common aperture of the genital and alimentary canal. The penis is simple, wedge-shaped, and is usually seen protruding dorsally.

Female.—The last abdominal segment is deeply notched at the apex, where the anus is situated. The vagina opens on the ventral surface.

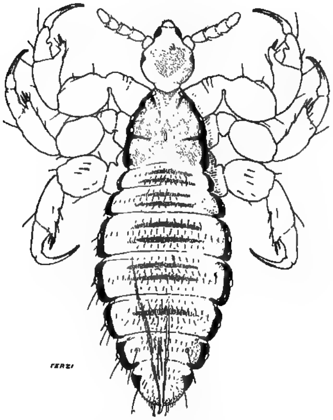

FIG. 209.—PEDICULUS HUMANUS L. (MALE). × 25.

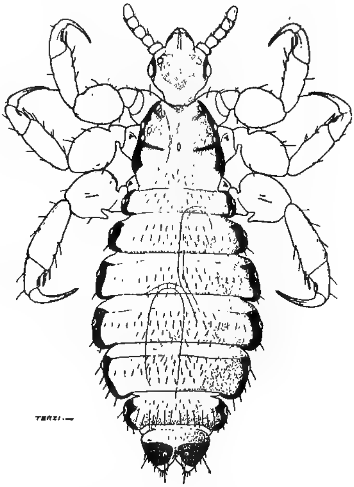

FIG. 210.—PEDICULUS HUMANUS L. (FEMALE). × 25.

Life-History.—The female lays fifty to sixty eggs, which are attached firmly to the hairs by the secretion of the cement gland. In about six days these eggs hatch. The young pediculi become fully developed in fourteen to twenty days.

Pathogenicity.—It produces a form of impetigo if its bites are infected.

Treatment.—White precipitate ointment or common paraffin oil may be used.

Pediculus corporis de Geer 1778.

Synonyms.—*Pediculus vestimenti* Nitzsch 1818, *P. tabescentium* Alt 1824.

This louse lives in the folds and seams of the clothes.

Morphology.—It is larger than *P. humanus*, and has an oval, elongated head, with large antennæ. The thorax is more segmented than in *P. humanus*, and the legs more developed, with larger claws.

Life-History.—It lays seventy to eighty eggs, measuring 0·7 to 0·9 millimetre, in the seams of the clothing, which hatch in three to four days, and become mature in fifteen to eighteen days.

Pathogenicity.—They cause much irritation.

Treatment.—Boil or steam the clothes in a sterilizer at 212° F.

Phthirius pubis Linnæus 1758.

Synonyms.—*Pediculus pubis* Linnæus 1758, *P. inguinalis* Reichard 1759, *Phthirius inguinalis* Leach 1815, *P. pubis* Küchenmeister 1855.

P. pubis is the pubic or crab-louse, and is more common on men than on women. It usually infests the pubic hairs, but may also be found on the eyelashes and on the eyebrows.

Morphology.—The body in general is flat and broad, with a rounded head bearing antennæ with five segments, and two small eyes. There is a neck.

The broad, flat thorax is merged into the abdomen, and carries three pairs of legs, of which the anterior pair is slender, and possesses a straight claw suitable for walking, and the two posterior pairs have claws suitable for clinging.

The female measures 1·5 to 2 millimetres in length by 1·5 millimetres in breadth. The male is half the size of the female.

Life-History.—The female lays ten to fifteen eggs, which it attaches to hairs. These hatch in seven days, and the resulting pediculi become mature in about two weeks.

Pathogenicity.—It produces often a dermatitis, with itching and a greyish discoloration of the skin, said by Dugnet to be caused by a pigment produced by the parasite. Erasmus Wilson says that reddish deposits may be seen on the hairs, due to the fæcal matter of the parasite.

Treatment.—White precipitate ointment or some other mercurial preparation.

Hæmatopinus.

This genus is not very distinct from *Pediculus ;* two species are, however, known on man, and several on monkeys, dogs, horses, and many domestic animals.

FAMILY 2. RICINIDÆ.

Siphunculata with head larger than the thorax, and possessing dark horny bands arranged in different systems.

The Ricinidæ are subdivded into :

SUBFAMILY 1. PHILOPTERINÆ.—Antennæ with three or five segments. It includes the genus of *Trichodectes*, parasitic on mammals.

SUBFAMILY 2. LIOTHEINÆ.—Antennæ with four segments.

The genera include *Gyropus, Trinoton, Colpocephalum,* and *Menopon.*

ORDER HEMIPTERA.

Hexapoda with four wings, the front pair being either membranous or half horny and half membranous, but both pairs may be wanting in the parasitic species. Mouth suctorial. Metamorphosis incomplete.

The Hemiptera include the cochineal insect, *Coccus cacti* , the Aphidæ, plant-lice ; and, in particular, the cicadas, whose shrill notes wake the quiet of an African forest. The anterior wings are called hemelytra, and usually consist of three portions :

1. The clavus—the hard, coriaceous portion next to the scutellum.
2. The corium—hard, coriaceous portion occupying the whole of the area between the clavus and the membrane.
3. The membrane—apical portion.

The posterior pair are the true wings.

In the Cimicidæ the corium is divided into three portions :

1. Internal—corium proper.
2. External and basal—embolium.
3. External and apical—cuneus.

The order is divided into two suborders :

SUBORDER I. HOMOPTERA.—With both pairs of wings membranaceous.

SUBORDER II. HETEROPTERA.—With the front pair of wings half horny.

The first will not be considered here.

HETEROPTERA.

This suborder has two series :
Series 1. *Gymnocerata.*—Antennæ conspicuous.
Series 2. *Cryptocerata.*—Antennæ hidden.

GYMNOCERATA.

The families of importance to us are :

Cimicidæ.
Reduviidæ.
Lygæidæ.
Hydrometridæ.

These families can be diagnosed, according to Distant, in the following manner :

A. Species not aquatic ; abdomen not clothed beneath with a silvery, velvety pubescence ; scutellum not reaching to the base of the membrane nor to the middle of the abdomen.

(1) Mesopleuræ and metapleuræ composed of one piece ; hemelytra without cuneus ; tarsi three-jointed.

(*a*) Rostrum not bent at the base ; lying in repose against under-surface of head ; antennæ inserted below a line drawn from the centre of the eye to the apex of the face ; ocelli present—Lygæidæ.

(*b*) Rostrum short, stout, bent at the base, so that in repose it does not lie against under surface of the head ; ocelli behind eyes ; hemelytra complete with distinct membrane —Reduviidæ.

(2) Mesopleuræ and metapleuræ composed of seven pieces ; hemelytra with a cuneus and an embolium ; ocelli absent—Cimicidæ.

B. Abdomen clothed beneath with a silvery velvety pubescence. Species aquatic or semi-aquatic ; antennæ four-jointed—Hydrometridæ.

FAMILY CIMICIDÆ.

Ocelli absent ; elytra very short and broad, so that the abdomen is left uncovered ; tarsi three-jointed.

This family contains the bugs, with four genera, but only *Cimex* will be dealt with here.

Genus.—*Cimex* Linnæus 1758.

Synonyms.—*Acanthia* Fabricius 1803, *Klinophilos* Kirk 1899.

Cimicidæ with short, broad head with two prominent eyes, but no ocelli ; antennæ four-jointed, apical joints slender ; elytra rudimentary and lie over the metathorax ; prothorax semilunar, with extended anterior angles ; abdomen uncovered, with seven segments and an eighth anal appendage ; legs slender ; anterior tibia twice as long, and posterior three times as long, as the tarsi, which are three-jointed; proboscis flexed into a groove beneath the head and prothorax.

Type Species.—*Cimex lectularius* Linnæus. The species known at present are:

1. *Cimex lectularius* Linnæus 1758.
2. *C. rotundatus* Signoret 1852.
3. *C. ciliatus* Eversmann 1841.
4. *C. pipistrelli* Jenyns 1839.
5. *C. columbarius* Jenyns 1839.
6. *C. hirundinus* Jenyns 1839.
7. *C. inodorus.*

Only the first three need concern us.

Cimex lectularius Linnæus 1758.

Synonyms.—*C. lectularius* Merrett 1667, *Acanthia lectularius* Fabricius 1794.

This is the common bed-bug found all over the world, as far as is known, but Patton has recently shown that other species have been mistaken for this insect. It was well known to the ancient peoples of Asia and to the Romans, who called it *Cimex*, but it is believed to have only reached England in 1503, which is rather questionable. Originally it was known as the wall-louse or chinch, and the term 'bed-bug' is apparently of recent origin. Both males and females suck blood, and are suspected of spreading Obermeyer's relapsing fever.

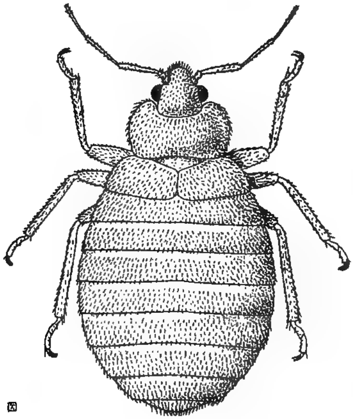

FIG. 211.—CIMEX LECTULARIUS L. (FEMALE). × 10.

Morphology.—It is reddish-brown in colour, with short, broad head carrying two eyes, two antennæ composed of four segments, of which the first and second are stout, and the third and fourth slender. The mouth consists of a proboscis, which is composed of an upper part—the labrum—which is small, and a lower curved portion. This is large and jointed—the labium—inside which are four stylets, the two outer being the mandibles, and the two inner the maxillæ. There are no pàlpi. The prothorax is semilunar, with two rounded horns. The dorsum is raised in the median line. The mesothorax is triangular, with the apex posteriorly. The metathorax is covered dorsally by the elytra, which are two small chitinous plates belonging to the mesothorax, but consist of clavus, corium, empodium, cuneus, and membrane. The abdomen, which is rounded in shape, with seven segments and an eighth anal appendage, is broadest opposite the third segment. Posteriorly it is covered with round hairs. Length, 5 to 6 millimetres. Male smaller than female, with penis flexed into a notch between seventh and eighth segments.

Internal Anatomy.—The mouth leads into the pharynx, beneath which is a syringe organ or salivary pump, into which the salivary glands open. The pharynx leads viâ the œsophagus into a large crop. There is the usual mid-gut, intestine, and rectum.

Life-History.—They live in cracks in floors, walls, and furniture during the day, and issue forth at night to suck blood from human beings. They are capable of emigration from house to house. The female lays some fifty eggs three or four times a year. Complete development is said to require eleven weeks, but may be completed in as short a time as seven weeks.

The eggs, which are oval, 1·12 millimetres in length, and white in colour, take about seven to ten days to hatch. The larva grows slowly, moulting about five times, at intervals of about eight days, after which the wing-pad appears, showing that the adult stage is reached. They feed upon blood only.

Pathogenesis.—It is quite possible that they spread *Spirochæta recurrentis*, the cause of Obermeyer's relapsing fever. The effects of their venom have already been described.

Bite.—In biting, they extend the proboscis, and feel about, testing the skin with the delicate hairs, then pierce it by the stylets, and inject saliva by the syringe, causing congestion of the area, when the blood runs up the grooves in the stylets by capillary attraction into the pharynx.

Smell.—The peculiar odour is due to the secretion of sac-like glands situated at the base of the abdomen, and opening on each side of the metasternum. The secretion is a clear, oily, volatile liquid, which is supposed to be protective in function.

Cimex rotundatus Signoret 1852.

Synonym.—*Cimex macrocephalus* Fieber 1861. This is the Indian bed-bug, which is found in India, Ceylon, Burma, Assam, and Malaya in Asia, and also in Sierra Leone, Mauritius, Réunion, St. Vincent, and Porto Rico.

Morphology.—*C. rotundatus* differs from *C. lectularius* by being darker in colour, with a shorter, narrower head, with a prothorax with rounded borders, and with a longer, narrower abdomen.

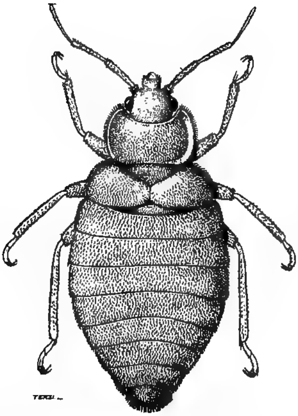

FIG. 212.—CIMEX ROTUNDATUS SIG. (MALE). × 10.

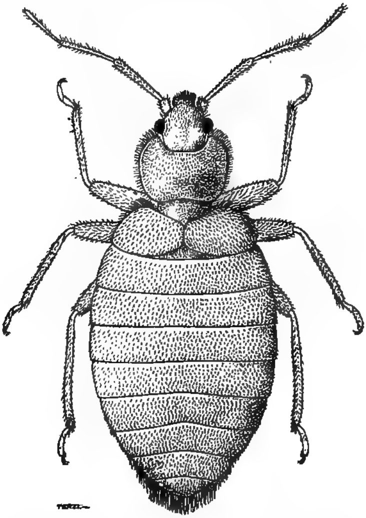

FIG. 213.—CIMEX ROTUNDATUS SIG. (FEMALE). × 10.

Pathogenesis.—According to Patton it spreads *Leishmania donovani*, the parasite of kala-azar or tropical splenomegaly.

Cimex ciliatus Eversmann 1841.

This bug is found in Kasan, in Russia. It requires reinvestigation.

Morphology.—It is smaller than *C. lectularius*, yellowish-red in colour, and thickly covered with hairs. Length, 3·3 millimetres.

Pathogenesis.—Not known.

Prophylaxis.—Bugs are by no means without their enemies, of which the most marked is the common red house-ant (*Monomorium pharaonis*), while another enemy is the common cockroach; but, despite these foes, bugs are extremely common in tropical hospitals. The first step in prophylaxis, of course, is strict cleanliness, and the use of painted iron bedsteads which can be easily taken to pieces and washed. Another good means is to make use of mattresses and pillows covered with Willesden canvas, which can easily be washed. The mattress should be in sections, and not all in one piece, as otherwise it is difficult to manipulate. The most useful substances for killing bugs are acetic acid, camphor, and carbolic acid. Acetic acid poured into the joints of a bedstead is said to kill the bugs rapidly. Kerosene is often used, but does not appear to be very effective. Apart from bedsteads, the whole room may be infected, in which case fumigation with sulphur is quite the best remedy, 4 ounces being burnt for each 1,000 cubic feet of space, and the room left closed for four or five hours, in order that the gas may act thoroughly.

REDUVIIDÆ.

Gymnocera with long, narrow heads and distinct neck. Eyes large and prominent; proboscis short, thick, and curved; antennæ long, slender at the tip; legs long; elytra with three divisions when present; tarsus three-jointed.

The genera which will be noted here are: *Reduvius, Conorhinus, Coriscus, Rasahus, Melanolestes.*

In addition, it may be mentioned that Wellman found *Phonergates bicoloripes* Stäl, which is locally known as 'ochindundu,' in the act of sucking the juices of *Ornithodoros moubata.* It is well known that the Reduviidæ attack other insects and ticks. He also mentions that the same insect produces a more painful effect upon man than the bite of the tick *O. moubata.*

Reduvius.

Body moderately elongate, head oblong, ante-ocular portion of head larger than post-ocular portion; eyes large, completely extending across the lateral parts of the head; rostrum with second joint much larger than first; pronotum transversely constricted before the middle anterior lobe with a strong central sulcus or fissure, which is broadly extended to the disc of the posterior lobe. Anterior much shorter than posterior lobe. Scutellum with apical spines; legs moderately long and slender; anterior femora normal; anterior tibiæ furrowed.

Reduvius personatus Linnæus.

This is the wheel or masked bug found in Europe and the United States and celebrated for the severity of its bite; for it causes pain, swelling, and irritation in the affected area which may last as long as a week.

Conorhinus.

Head long, porrect, more or less distinctly impressed behind eyes; rostrum with first joint very much shorter than second; antennæ inserted on the sides of the head about midway between eyes and apex; ocelli placed very far apart; prosternum broadly sulcated; abdomen frequently with the disc flattened; posterior tibiæ longer than the femora.

The species of *Conorhinus* are mostly found in South America, and live on the blood of mammals and of insects, including bed-bugs. Some of the more important are: *C. sanguisuga, C. rubrofasciatus* de Geer, *C. renggeri* Herrich-Schäffer, *C. nigrovarius, C. protractus.*

Conorhinus sanguisuga Lec.

This is the blood-sucking cone-nose of America, which feeds upon the blood of insects, including bed-bugs, and mammals, including man. The bite is very severe, and causes much swelling and irritation. It is a night-flier, and has an odour like that produced by bugs.

Morphology.—It is a large dark brown insect, with pink markings and a flattened body and very narrow pointed head, with a strong, thick, long proboscis. The thorax is provided with wings.

Life-History.—The eggs when first laid are white, but later change to yellow, and finally to pink. The larva hatches in about twenty days, and is very active. It moults twice and becomes the pupa, which also moults twice, the last stage showing wing pads. The pupa is also active.

Habits.—In addition to feeding upon blood, these insects may suck the juices of decomposing flesh.

Pathogenesis.—Its bite at times is followed by severe general symptoms, such as swelling in different parts of the body, nausea, etc., as well as local pain.

Remedy.—Sweet oil is advised as a remedy for the local pain.

Conorhinus rubrofasciatus de Geer.

This is the Malay bug, found in Africa, Sierra Leone and Madagascar, in Asia, Ceylon, India, Malaya, China, and the Philippine Islands. It is said to produce a very severe bite.

Conorhinus renggeri Herrich-Schäffer.

This is the black bug of the Pampas.

Conorhinus nigrovarius.

This is the 'bichugue' of South America, and bites severely.

Conorhinus protractus.

This is the big bed-bug of Utah.

Conorhinus Sp. (?)

Recently Chagas has demonstrated that a *Conorhinus* of undetermined species is a carrier of *Trypanosoma cruzi*. This *Conorhinus* attacks men and animals, and, owing to its habit of biting the face, is called 'Barbeiro' by the indigenous population. Probably this is the same species as *C. sanguisuga* Lec.

Coriscus.

Coriscus subcoleoptratus Kirby 1837 has once been recorded as a human blood-sucker in the United States.

Rasahus.

Rasahus biguttatus Say 1831 is found in the houses in Cuba, Panama, and Para, where it really seeks the bed-bug, but bites man also.

Melanolestes.

Melanolestes morio Erichson 1848. Found in Guiana and Mexico and U.S.A. under stones during the day. Bites man.

Lygæidæ.

Hemiptera with the scutellum not reaching to the middle of the body; proboscis sheath, four-jointed; ocelli present; antennæ elongate, inserted well down on the sides of the head. They are mostly vegetal feeders, but *Lyctocoris campestris* Fabricius, in Europe; *Rhodinus prolixus* Stäl 1857, in Colombia, Cayenne, and Venezuela; *Eulyes amœna*, in Borneo and Java; and *Arilus carinatis* Forster, Brazil, are known to bite man.

Hydrometridæ.

The Hydrometridæ, or water-bugs, are interesting to the student of tropical medicine, because Patton has traced out the development of a Crithidia resembling *Leishmania donovani* in one of them, as has been described in the chapter on Protozoa.

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CHAPTER XIX

BIOLOGICAL CAUSES OF DISEASE (*continued*) —THE DIPTERA

CULICIDÆ AND THEIR ALLIES

Diptera : Morphology, Classification—Culicidæ—Corethridæ—Chironomidæ—Psychodidæ—Simulidæ—References.

DIPTERA.

HEXAPODA with two well-developed transparent wings and two rudimentary wings in the form of halteres. Mouth parts well developed, capable of biting or sucking. Mesonotum forms by far the larger portion of the thorax. Metamorphosis is complete.

The Diptera are by far the most important order of the Hexapoda as regards tropical medicine, for they include the blood-sucking flies, which are capable of carrying disease; also certain flies which cause disease by depositing their eggs in cavities or on the surface of the body, with the result that the larvæ enter the nose, and cause disease by gnawing away mucous membrane, cartilage, and even bone, or the alimentary canal, in which they may cause serious symptoms. Apart from these, it must be remembered that flies, particularly the common house-fly, may mechanically, either externally or by its alimentary canal, carry and deposit germs on food, by which means human beings become infected with disease.

Morphology.—The most important points in the morphology of the Diptera in general may be briefly mentioned.

Head.—The head in certain families shows an anterior depressed area, the lunula, bounded by an arched suture, which passes over the base of the antennæ. This is the inverted 'ptilinum,' or vesicle, by which the imago breaks its way out of the pupa. With regard to the antenna, it is of great importance whether it is many- or few-jointed. In the latter case it often carries an arista on the third joint, which may be looked upon as representing the remainder of the larger antennæ of other species.

The mouth parts, though composed of the typical labrum, epipharynx, maxillæ, mandibles, hypopharynx, and labium, will be found to be very different in the various species of biting flies. More especially are the labial palps altered in *Glossina* and *Stomoxys*, becoming armed with teeth and capable of making the hole in the skin which is necessary for the sucking of the blood.

Thorax.—In many cases the thorax is largely composed of mesothorax, the pro- and metathoraces being much reduced. The wings are of importance, first, because in the Muscidæ some genera possess a prolongation backwards, called the squama, which conceals the altere. The venation of the wing has a peculiar nomenclature, which will be more fully explained under the heading Culicidæ, but which may here be compared with the typical arrangement of Comstock and Needham, from which it differs mainly by the form of coalescence called 'inward,' which means that two veins have coalesced from the tip towards the base of the wing.

Typical Names.		Dipteral Names.
Costa		Costa.
Subcosta		Subcosta.
Radius 1		First Longitudinal.
Radius 2	Coalesced	Second Longitudinal.
Radius 3		
Radius 4	Coalesced	Third Longitudinal.
Radius 5		
Media 1	Coalesced more or less	Fourth Longitudinal.
Media 2		
Media 3		
Media 4		
Cubitus 1		Fifth Longitudinal.
Cubitus 2		
Anal 1		Sixth Longitudinal.
Anal 2		
Anal 3		Seventh Longitudinal.

There can, however, be no doubt that Comstock and Needham's classification is by far the best. In addition to the longitudinal veins there are, however, several transverse veins, viz.:

1. The humeral from the costa to subcosta.
2. The radio-medial or anterior from the radius to the media.
3. The distal medio-cubital or posterior from the media to the cubitus.
4. The proximal medio-cubital or anterior basal.
5. The cubito-anal or posterior basal.

The wing shows a costal cell, generally subdivided by the humeral vein, a subcostal, a marginal, a variable number of submarginal, a posterior and an anal cell. The second anal vein is often wanting, and represented by merely an incrassation. In addition there are generally an anterior or radial, a posterior medial, and an anal or cubital basal cell. The first submarginal and the second posterior cells are often called the fork cells. In the first posterior cell it is important to note whether it is closed, and does not reach the margin of the wing owing to the junction of the media with the radius, or open, or partially open, and does reach the margin of the wing. A discoidal cell in the middle of the wing is present in some genera. It is bounded either by the media or by that vein and the cubitus.

The legs possess the usual number of segments. The fifth tarsal segment carries usually two claws and often two pulvilli or pads, while between them lies the empodium in the form of a bristle or third pad, which may be looked upon as a sixth tarsal or claw segment.

Abdomen.—This has usually nine segments, which may be reduced by the fusion of segments, especially in connection with the male and female generative organs. The genitalia, especially the male, are of importance in classification, and will be mentioned in detail under the heading Culicidæ.

The body is adorned by scales and hairs. The former have been made use of by Theobald to classify the Culicidæ, while the latter may be strongly developed in places, and have been used in flies as a help in classification, and are of the utmost importance in fleas.

Flies are usually modest in colour, being often yellowish, brownish, or blackish, but some of the Culicidæ—*e.g.*, *Megarhinæ*—are brilliantly coloured. The colours depend partly upon pigments and partly upon interference with or reflection of light.

Life-History.—The female generally lays eggs; more rarely a larva is produced directly, as in *Glossina.* The eggs are laid in some material which will be useful to the larvæ—*e.g.*, the eggs of Culicidæ in water and the eggs of Muscidæ often in decomposing matter. The larva is generally a very active, vigorously-feeding little grub, which may or may not have a distinct head. The pupa may either remain in the old larval skin which forms the puparium, such a pupa, often seen in the Muscidæ, belongs to the coarctate type, or it may not be so enclosed, but the body and appendages being closely united, it forms the obtectate type. The imago may escape from its pupal skin by a T-shaped slit (Orthorrhapha), or it may escape by a circular opening (Cyclorrhapha).

Classification.—The Diptera may be classified as follows, according to the characters of the pupa, larva, and antennæ:

SUBORDER I. ORTHORRHAPHA.

Diptera without lunula or ptilinum. Larva with a distinct head. Pupa obtectate. Imago escapes by T-shaped opening.

Section 1. Nematocera.—Orthorrhapha with antennæ composed of more than six joints, with the joints, except the first two, similar; without arista. Palpi four- or five-jointed.

Families.—Culicidæ, Corethridæ, Chironomidæ, Psychodidæ, Simulidæ, Blepharoceridæ, etc.

Section 2. Brachycera.—Orthorrhapha with antennæ in which the joints differ from one another, with or without arista, which, when present, is usually terminal.

TRIBE 1. BRACHYCERA HOMŒODACTYLA. — Orthorrhapha brachycera with three well-developed footpads. Larva with a projecting posterior stigma.

Families.—Tabanidæ, Leptidæ.

TRIBE 2. BRACHYCERA HETERODACTYLA. — Orthorrhapha brachycera with two or three footpads. In the last case the middle is different from the two side-pads. Some species without footpads. Posterior stigma of the larva in front of the body-end.

Families.—Asilidæ, Empidæ.

SUBORDER II. CYCLORRHAPHA.

Diptera with a lunula and usually a ptilinum. Antenna with always three joints and an arista. Palpi one-jointed. Mandibles absent. Maxillæ rudimentary. Discoidal cell bounded by the media and cubitus. Abdomen with seven segments at the most, often with less.

Section 1. Aschiza.—Cyclorrhapha with a clearly defined lunula, but a rudimentary ptilinum. Arista poorly developed.

Families.—Not of interest in tropical medicine.

Section 2. Schizophora.—Cyclorrhapha with lunula; at times absent, but the arched suture over the antennæ is well defined. Ptilinum usually well developed. Antennæ lie in separated hollows. Arista well developed.

Tribes.—Muscidæ acalyptratæ and Muscidæ calyptratæ.

SUBORDER III. PUPIPARA.

Diptera with rudimentary or no wings; parasitic on vertebrates. The fully developed larvæ are passed directly from the body of the imago without a free-living egg stage.

SUBORDER IV. SIPHONAPTERA.

Diptera with a laterally compressed body and distinctly separated thoracic rings, but without wings.

SUBORDER ORTHORRHAPHA.

SECTION NEMATOCERA.

FAMILY CULICIDÆ.

Orthorrhapha nematocera with a long piercing proboscis, and a body more or less clothed with scales and hairs. Antennæ with whorls of hairs or plumes, which may be dense and long in the male, though scanty in the female. Wings with six to seven longitudinal veins, with scales and two distinct fork cells. The costa passes all round the wing, and carries scales, which form a fringe. Metamorphosis complete.

The Culicidæ include the flies which we call mosquitoes, a word which is derived from the Spanish, meaning a little fly, and are the same as gallinippers in America. The genus *Culex* was formed by Linnæus in 1790 for the gnat *Culex pipiens;* the genus *Anopheles* from a Greek word meaning harmful, by Meigen in 1818; the genus *Stegomyia* by Theobald in 1901. A great many other genera have also been described, but are not so important in tropical medicine as these three. Among the early workers in this field of research special prominence must be given to the names of Arribalzaga and Ficalbi.

The great worker at the Culicidæ is Theobald, whose monograph on the 'Culicidæ of the World' should be referred to for detailed information with regard to this subject. To this observer tropical medicine is indebted for clearly defining a most useful method of classification. He has also split up the old genera of *Culex* and *Anopheles* into several genera, thus making it easier to refer specimens to their proper position.

Careful dissections of *Anopheles* have been made by Nuttall and Shipley, and of *Culex* by Christophers, while the larva and pupa of *Anopheles* have been studied in detail by Imms.

As the *Anopheles* is, without doubt, of the greatest importance to medical men, its anatomy will be described.

Morphology.—*Anopheles maculipennis* Meigen has been studied by Nuttall and Shipley, whose account is followed in the description given below.

The body of a mosquito is divided into (*a*) head, (*b*) thorax, (*c*) abdomen.

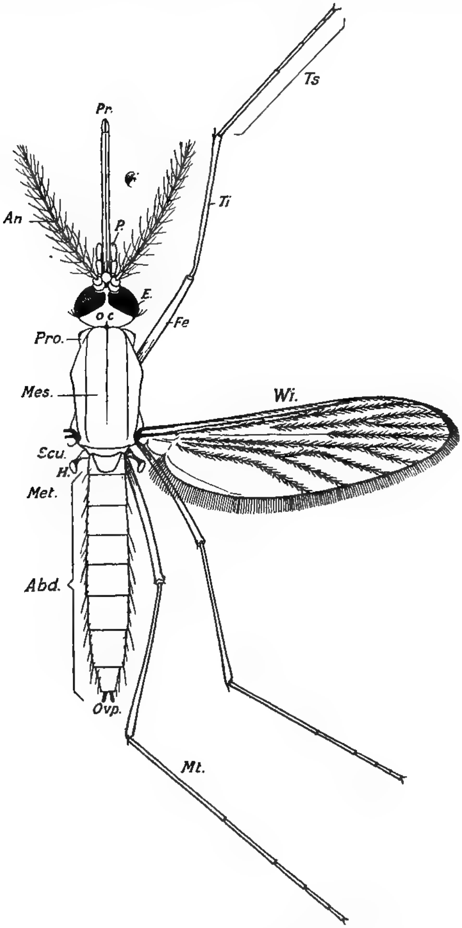
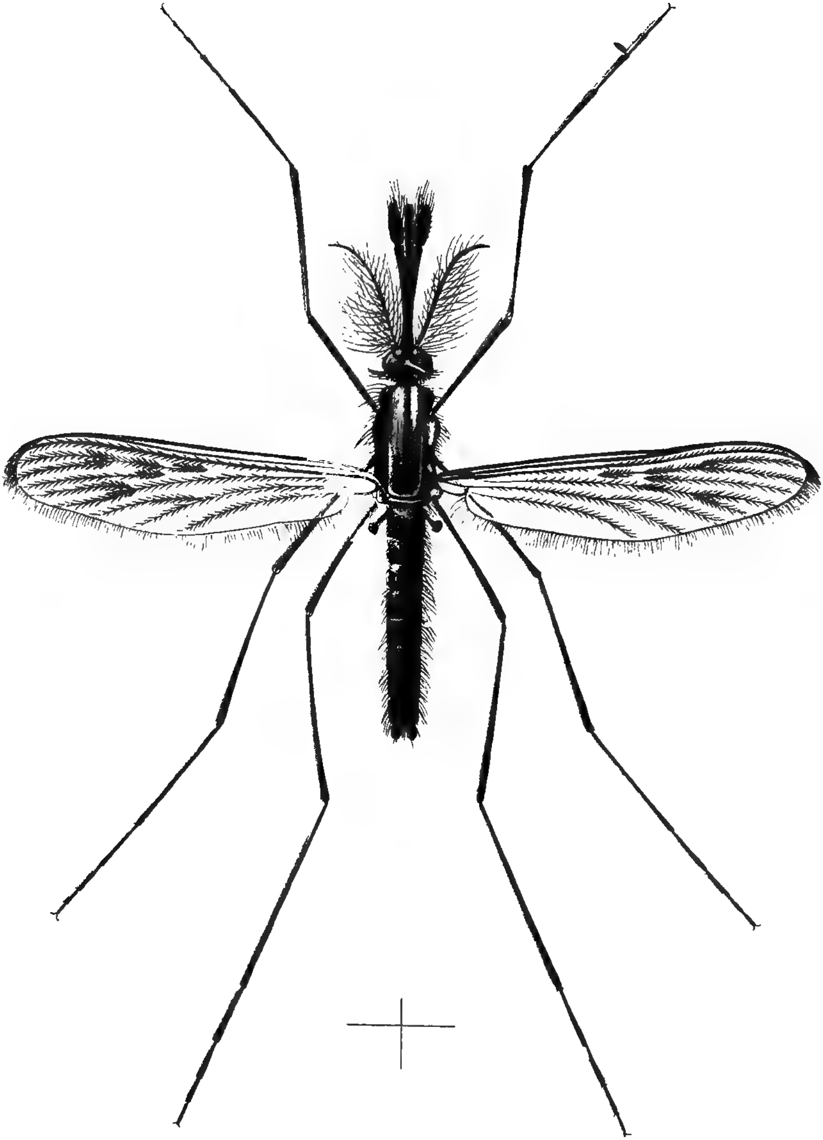


FIG. 214.—DIAGRAM OF A MOSQUITO, AFTER THEOBALD, FROM THE 'CULICIDÆ OF THE WORLD.'

Pr., proboscis; *P.*, palp; *An.*, antenna; *E.*, eye; *Oc.*, occiput; *Pro.*, prothorax; *Mes.*, mesothorax; *Scu.*, scutellum, behind which is seen (*Met*) the shield-like post-scutellum; *H.*, haltere; *Abd.*, abdomen; *Ovp.*, ovipositor; *Wi.*, wing; *Fe.*, femur; *Ti.*, tibia; *Mt.*, metatarsus; *T.S.*, tarsus—the line indicating the tarsus is made to include the metatarsus, which is sometimes regarded as the first tarsal joint.

(*a*) *Head.*—The most conspicuous objects on the head are the two large reniform, often brilliantly coloured eyes, which lie on a piece of exoskeleton, called the 'epicranium,' which covers the whole head, except in the ventral median line, where the gula can be seen. Dorsally the eyes nearly meet,

PLATE II.

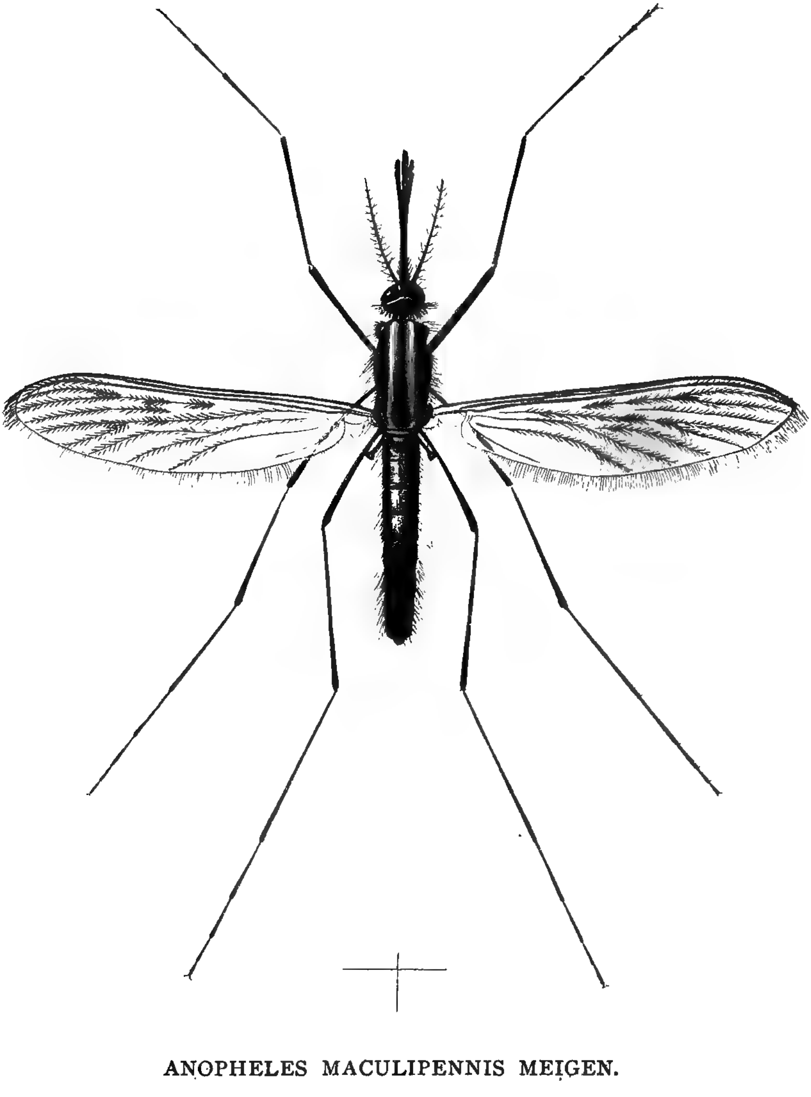


ANOPHELES MACULIPENNIS MEIGEN.

MALE.

ton & Sons, Lith, Edin.

To face Plate III.



ANOPHELES MACULIPENNIS MEIGEN.

FEMALE.

(After Austen, by kind permission of the Trustees of the British Museum.)

Waterston & Sons Lith. Edin.

being separated by a space called the 'vertex,' in front of which is the frons, which carries a pair of antennæ, different in male and female. The male antenna has sixteen segments, of which the first segment is very small; the second is globular, and contains an auditory organ; the third is long, and the fourth to the fifteenth carry twenty-five to thirty hairs in whorls at the proximal end of each segment. The sixteenth segment is about half as long as the penultimate. So dense are the whorls of verticillate hairs in the male that the term 'plumose' is applied to the whole antenna. The base of the sixteenth segment carries six hairs, and the tip is rounded. The female antenna consists of fifteen segments. The first is very small, merely a ring of chitin; the second is deeply hollowed for the third segment, which is the longest. The proximal ends of the fourth to the fifteenth carry six large hairs. The tip of the fifteenth segment bears fine hairs. These few hairs produce quite a different appearance in the antennæ, which are called 'pilose.'

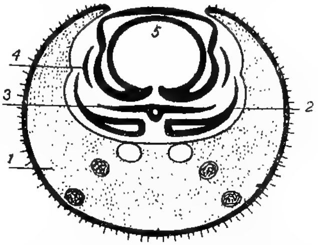


FIG. 215.—TRANSVERSE SECTION OF THE PROBOSCIS OF ANOPHELES MACULIPENNIS MEIG.

(After Nuttall and Shipley, from the *Journal of Hygiene*.)

1, Labium; 2, maxilla; 3, hypopharynx, with salivary duct; 4, mandible; 5, labrum epipharynx with the figure (5) placed in the blood tube.

In front of the frons a sclerite called the 'clypeus,' belonging to the exoskeleton of the head, projects forwards, under cover of which the mouth appendages appear as a median proboscis and two lateral palpi.

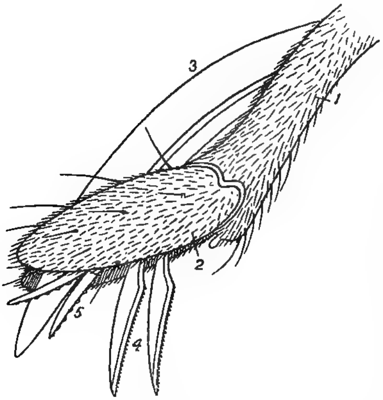


FIG. 216.—DISTAL END OF THE PROBOSCIS OF ANOPHELES MACULIPENNIS MEIGEN.

(After Nuttall and Shipley, from the *Journal of Hygiene*.)

1, Labium; 2, labellæ; 3, labrum epipharynx; 4, maxillæ; 5, mandibles.

These mouth parts are made up of the following (*vide* Fig. 26):

1. Labrum, or upper lip, with which is combined the epipharynx to form the labrum-epipharynx.
2. The mandibles.
3. The first air of maxillæ to which the palpi belong.
4. The hypopharynx.
5. The second pair of maxillæ, which have united together to form the lower lip or labium.

The labrum-epipharynx commences at the head end as two separate chitinous structures: the more dorsal, continuous with the clypeus, is the labrum, and the more ventral, continuous with the chitinous lining of the mouth cavity, is the epipharynx; the part in the proboscis forms a deep groove, open ventrally. In the female its free end is sharp and pointed; in the male it is truncated.

The mandibles are absent in the males, while in the female they appear as yellow delicate chitinous blades, the base of which is attached to the sides of the labrum, and the apex is knife-shaped, with its edge serrated by thirty-one fine teeth (*vide* Fig. 27).

The first maxillæ are chitinous rods attached posteriorly to the side of the base of the labium, which is here swollen, and carries on its outer angle the palp. It is continuous posteriorly with a chitinous bar, which runs backwards nto the head, and affords attachment to several muscles. The free extremity of the maxilla has thirteen teeth (*vide* Fig. 28).

The maxillary palps project on either side of, and dorsal to, the proboscis. They are five-jointed and covered with scales. In the male, the distal end of the third segment is broadened, and the whole fourth and fifth segments are broad and flat, giving a spatulate appearance to the tip. The length of these palpi varies in the different genera of the Culicidæ, as will be mentioned under the heading of Classification.

The hypopharynx takes its origin just above the base of the labium in a solid mass of chitin, which is pierced by the salivary duct, which is a canal 35 to 36 μ in diameter. In the male the hypopharynx is fused with the labium.

The second maxillæ are united together to form a lower lip, or labium, which is curved dorsally so as to form a deep groove, in which the first maxillæ ie ventrally and laterally, with the hypopharynx situated dorsally and mesially, and the labrum-epipharynx dorsally with the mandibles on either side. The distal end carries two short segments called 'labellæ,' which are movable on hinge-joints. Between these labellæ there is a projection of the labium connected with them by a thin membrane — Dutton's membrane—which is stretched during the act of biting. Through this membrane filarial embryos escape from the interior of the labium. The labium itself is composed of a double cuticular wall carrying scales on its exterior, and enclosing internally a cavity containing muscles, etc., among which the filarial embryos can lie. There are, therefore, two tubes in the proboscis: the first, large, formed by the labrum-epipharynx, and the hypopharynx, is the blood-tube, up which the blood is sucked into the pharynx; while the other, small, lying in the hypopharynx, is the salivary duct. The first is afferent, the second efferent.

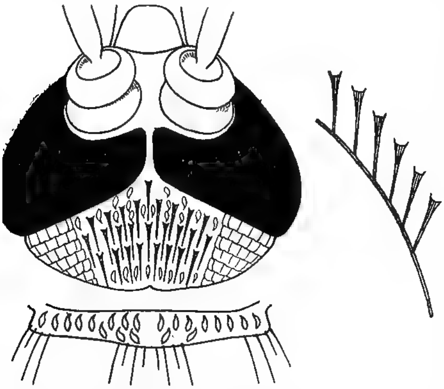


FIG. 217.—THE OCCIPUT AND SCUTELLUM OF AN ANOPHELINE MOSQUITO TO SHOW THE SCALE CHARACTERS.

At the side is seen the lateral aspect of the vertical scales.

(After Theobald, from the 'Culicidæ of the World.')

Behind the eyes there is an area of the head called the 'occiput,' which carries different kinds of scales in different genera, as is seen by the following diagram. These scales may be differentiated into narrow curved scales, upright forked scales, and flat scales, the presence and character of which have been made the means of classification. The upright forked and the curved scales occupy the middle area of the occupit, and alone are met with in this species; but quite different arrangements are met with in other genera. The extreme posterior area of the head is the nape. Below the eye laterally is the area of the head called the 'gena.' At the back of the head is the occipital foramen, through which the soft structures pass to the neck.

Neck.—The neck is the soft connection of the head with the thorax. It is strengthened with chitinous rods.

Thorax.—The thorax shows the usual three divisions into pro-, meso-, and metathorax, but of these the mesothorax is much the largest, and is often called 'the thorax'; in fact, the pro- and metathorax are hard to see. It will be remembered that a typical thoracic segment should show dorsally a notum, composed of præscutum, scutum, scutellum, and post-scutellum; ventrally a sternum, and laterally a pleuron, consisting of episternum and epimerum.

On the posterior portion of each side of the neck may be seen a small sausage-shaped sclerite, called the patagium, in front of which is the neck sclerite, while posteriorly there is another sclerite reaching as far as the first thoracic spiracle. Below these, and reaching to the coxa of the first leg, is still another sclerite. These four sclerites make up the prothorax. The patagium may represent a pronotum, the neck sclerite an episternite, and the posterior sclerite an epimerum, while the sclerite, connected with the coxa of the first leg, is undoubtedly a prosternum. This segment of the thorax carries the first pair of legs, and perhaps the first spiracle.

The interpretation of the parts of the prothorax presents considerable difficulty. Some authorities believe that there is no pronotum. The mesothorax is well developed, and presents dorsally a præscutum and scutum fused together, behind which is a trilobed area, the 'scutellum.' Behind this, again, is a shield-shaped area, looked upon by some observers as a metanotum, but more probably representing the postscutellum of the mesothorax. Laterally behind the first spiracle lies the episternum of the mesothorax, below and behind which is the mesosternum, wedged in between the second and third legs on each side. The two mesosterna are bound together by a chitinous bar.

Between the post-scutellum and the first abdominal segment lies the minute true metanotum. The metasternum is easily seen between the second and third pairs of legs, and the episternum of that segment lies just dorsal to the third coxa, and contains the second thoracic spiracle as well as carrying the haltere. The thorax is covered with hair-like curved scales, and its appendages are the legs and wings. There are three pairs of legs, one for each division of the thorax, which have the usual number of segments—coxa, trochanter, femur, tibia, metatarsus, and tarsus, the latter being four-jointed. The last joint of the tarsus carries the two claws or ungues, which may be toothed. In the first leg in the male the claw is single, and the first terminal tarsal segment is hollowed out. In the female all the legs terminate in a double hook, and the first tarsal segment is not hollow. The empodium, a median process

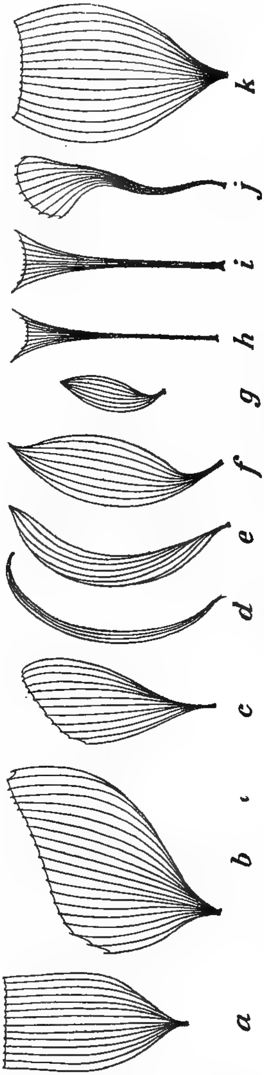


FIG. 218.—VARIOUS FORMS OF SCALES FOUND ON DIFFERENT PARTS OF A MOSQUITO.

(After Theobald, from the 'Culicidæ of the World.')

a, Flat scale from abdomen; *b*, broad wing scale; *c*, another broad wing scale; *d*, curved hair-like scale; *e*, narrow curved scale; *f*, flat spindle-shaped scale; *g*, small form of *f*; *h* and *i*, upright forked scales; *j*, twisted upright scale; *k*, inflated scale.

projecting between the ungues, is in *Anopheles maculipennis* reduced to a tuft of hairs. The arrangements of the ungues, however, vary very much in different genera and species.

The wings arise by their bases from the side of the mesothorax, between the scutum and the episternum. The anterior border of the wing is straight and thick, while the posterior is curved, and near the base is folded or indented twice to form squama and alula. The area of the wing, bounded by the by the squama and alula, is broken up by a series of thickenings and ridges from which the nerves take their origin. The base of the wing has a socket which fits on to a knob on the episternum. The veins of the wings are :

1. *The Costa.*
2. *The Subcosta,* which joins the Costa some distance from the apex of the wing.
3. *The Radius* 1 (*First Longitudinal*).—Runs from base to apex of the wing.
4. *The Radius* 2+ 3 (*Second Longitudinal*).—Commences in the middle of the wing, and shortly divides into two branches (Radius 2+ 3), enclosing a piece of the wing called the first submarginal cell.
5. *The Radius* 4+ 5 (*Third Longitudinal Vein*).—Commences in the middle of the wing and runs to the margin.
6. *The Media* (*Fourth Longitudinal Vein*).—Runs from the base of the wing to the margin, but forks (Media 1+ 2) to enclose the second posterior cell.

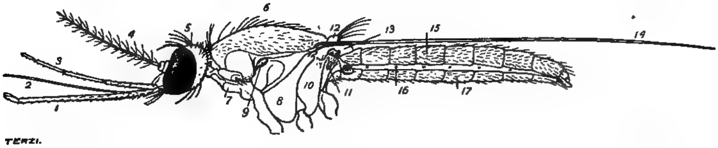


FIG. 219.—LATERAL VIEW OF ANOPHELES MACULIPENNIS MEIGEN.

(After Nuttall and Shipley, *Journal of Hygiene.*)

1, Labium ; 2, labrum-epipharynx ; 3, palp ; 4, antenna ; 5, occiput ; 6, mesothorax (præscutum and scutum) ; 7, prothorax ; 8, mesosternum ; 9, first thoracic spiracle ; 10, metasternum ; 11, second thoracic spiracle ; 12, scutellum ; 13, post-scutellum ; 14, wing ; 15, tergum ; 16, pleural membrane ; 17, sternum.

7. *The Cubitus* (*Fifth Longitudinal Vein*).—Runs from the base and forks (Cubitus 1+ 2) to enclose the third posterior cell.
8. *The Anal* 1+ 2 (*Sixth Longitudinal Vein*). — Runs a curved course from its margin.

In some mosquitoes there is a second anal vein (seventh longitudinal vein), but more often this is only indicated by a fold or incrassation. There may be a vena spuria or marking between the cubitus and the anal vein.

9. *Transverse or Cross Veins.*
    (*a*) The humeral, between the Costa and Subcosta.
    (*b*) The Radial, between Radius 2+ 3 and Radius 4+ 5 (second + third longitudinal veins).
    (*c*) The Radio-medial, between the Radius and Media (third + fourth longitudinal veins).
    (*d*) The Medio-cubital, between the Media and the Cubitus (fourth + fifth longitudinal veins).

These veins mark out the following cells :

1. The Costal cell, between Costa and Subcosta, but subdivided by the humeral vein.
2. Subcostal (Mediastinal) cell, between Subcosta and Radius 1.
3. Marginal cell, between Radius 1 and Radius 2+ 3.

4. First Submarginal cell, between Radius 2+ 3.
5. Second Submarginal cell, between Radius 2+ 3 and Radius 2+ 5.
6. First Posterior cell, between Radius 4+ 5 and Media.
7. Second posterior cell, between Media 1+ 2.
8. Third Posterior cell, between Media and Cubitus.
9. Fourth Posterior cell, between Cubitus 1+ 2.
10. Anal cell, between Cubitus and Anal 1.
11. Axillary cell, between Anal 1+ 2 and Anal 3, when present.
12. Spurious cell, behind Anal 3, when present.
13. Anterior Basal cell, bounded anteriorly by the Radius 1, posteriorly by the Media, and externally by the Radial transverse vein.
14. Posterior Basal cell, bounded anteriorly by the Media, and posteriorly by the Cubitus, and externally by the Medio-cubital vein.

The wing has scales on all its veins, except the cross and the spurious veins, which are arranged in two ways: (1) Two rows of flat scales on each vein; (2) lateral scales along each vein.

Generally these scales in the Anophelinæ are lanceolate, or long and narrow, but one genus, *Cyclolepppteron*, has large inflated scales. It will be found that scales vary much in the different genera and species, the principal forms of which may be gathered from the following. The posterior margin of the wing carries a fringe consisting of scales arranged as follows: (1) Flat scales; (2) long lanceolate scales; (3) short lanceolate scales alternating with the long lanceolate scales.

Abdomen.—There are eight segments in the abdomen, each of which consists of a dorsal plate, the tergum, and a ventral plate, the sternum, joined together by a pleural membrane, on which lie the abdominal spiracles, said to number six or eight by different observers.

On the posterior end of the terminal segment are the external genital organs. In the male these consist of a pair of large basal lobes, each terminating in a clasp segment armed with a claw, thus forming the clasper. The arrangements of the male genitalia vary so much that they have been used as a method of classification. Therefore it is necessary to explain in a general way the terms used with regard to the various parts which may be found. On the ventral surface of the basal lobe is the tubercle or lobe, called the claspette, while from their inner margin, near the base, a pair of claspers called harpagones, and more distally another pair, the harpes, project. Just at the junction of the two basal lobes are another pair of lobes—the setaceous lobes—which are believed to be the rudimentary ninth segment. The unci are absent in the Anophelinæ, but present as a pair of ventral processes in the Culicinæ. In the female there are the flap-like ovipositors.

The flat abdominal scales of the other Culicidæ are absent in the Anophelinæ, except in one genus.

Internal Anatomy.—A few points with regard to the internal anatomy of the mosquito may be mentioned.

ALIMENTARY CANAL.—The alimentary canal consists of: (1) Mouth; (2) buccal cavity; (3) pharynx, or pumping organ; (4) œsophagus and its pouches; (5) œsophageal valve, or proventriculus; (6) mid-gut; (7) ileum; (8) colon; (9) rectum; (10) anus (*vide* Fig. 29).

1. *Mouth*.—The mouth is the place where the maxillæ, mandibles, labrum-epipharynx, hypopharynx, and palps fuse together.

2. *Buccal Cavity*.—This extends from the mouth to the valve between it and the pharynx, and is lined with chitin, and has an upward and backward direction until it approaches the pharynx, when it turns suddenly upward. There is a portion of its roof which possesses a thinner cuticle than the rest of the buccal cavity, and has been called the soft palate. This structure possesses two spines directed downward into the lumen of the cavity, and has attached to it five pairs of palatal muscles. It is thought that as this membrane is wrinkled, and has muscles attached to it, it may indicate that it is used for suctorial purposes. Posteriorly there is a valve between the buccal cavity and the pharynx, lying on a level just behind the posterior end of the clypeus. This prevents the return of fluids to the mouth during pump-

ing. Annett and Dutton described a complicated sense-organ at the junction of the buccal cavity and the pharynx, but this has not been confirmed.

3. *Pharynx.*—The pharynx extends from the posterior end of the buccal cavity to nearly the posterior end of the head, where it ends in the œsophagus. It is considerably larger in the female than in the male, because the former sucks blood, while the latter does not. The anterior portion is tubular, and passes through the nerve ring between the supra- and infra-œsophageal ganglia. The posterior portion is triangular, and has a chitinous wall arranged into three plates, one dorsal and two latero-ventral.

Posteriorly, near the œsophagus, the triradiate pharynx is surrounded by a sphincter muscle, and the chitin of this portion is marked by ridges, which end in very fine spines, making a comb-like appearance, and possibly acting as a strainer. The three chitinous plates have powerful muscles attached to them, of which the two posterior dorsal dilators run from the occiput to the dorsal plate; the two anterior dilators (two pairs in the female) taking their origin from the vertex are inserted also into the dorsal plate, and the five-paired latero-ventral dilators arising from the lateral posterior angle of the head pass upwards and a little forwards to the latero-ventral plates. When these muscles contract, the triradiate pharynx becomes nearly circular, and when they relax the walls come together.

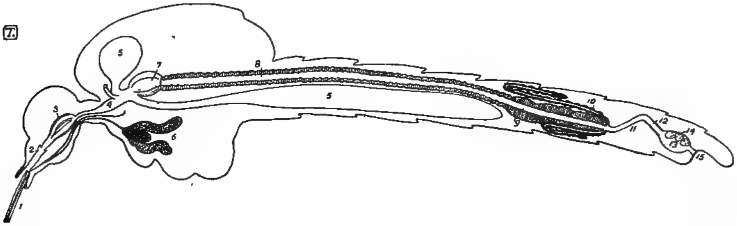


FIG. 220.—THE ALIMENTARY CANAL OF ANOPHELES MACULIPENNIS IN SITU.

(After Nuttall and Shipley, *Journal of Hygiene.*)

1, Proboscis; 2, buccal cavity; 3, pharynx; 4, œsophagus; 5, œsophageal pouches; 6, salivary glands; 7, proventriculus; 8 and 9, mid-gut; 10, Malpighian tubes; 11, ileum; 12, colon; 13, rectum; 14, rectal papillæ; 15, anus.

In this way the pharynx pumps the blood from the victim up the blood-tube in the proboscis into the alimentary canal.

4. *Œsophagus.*—The short œsophagus runs from the pharynx to the œsophageal valve. Anteriorly it is narrow, but posteriorly it expands so much that this portion is sometimes called the crop. It is lined with thin chitin, and has many bands of muscles attached to it. Its posterior end lies on a level with the origin of the first pair of legs, and at this situation it gives off three pouches, two dorsal and one ventral. The large ventral pouch opens into the œsophagus by a single opening in the middle line, and extends backwards under the alimentary canal to the level of the fifth, sixth, or seventh abdominal segment, when fully distended. In shape it is fusiform. The two small latero-dorsally placed pouches open into the sides of the œsophagus. All these sacs are lined with thin chitin, and have some slight musculature.

5. *The Œsophageal Valve or Proventriculus.*—The œsophageal valve is an annular thickening of the intestinal wall, due partly to circular muscles, which are capable of closing the lumen of the gut when they contract, and partly to an invagination of the more anterior portion of the gut into the more posterior, thus forming a valve. Projecting from it are six small protuberances, more marked in the larva than in the adult insect. Christophers considers that this portion of the alimentary canal is the proventriculus of other insects. It is not lined with chitin.

6. *Mid-Gut or Chylific Ventricle.*—The mid-gut is a straight tube running from the œsophageal valve at the level of the first pair of legs to the posterior limit of the sixth abdominal segment; but this varies as to whether it is filled with food or not. It consists of two parts: an anterior narrow, and a posterior more distended, often called the 'stomach,' which begins on a level with the second abdominal segment, and is the receptacle for the food. The wall of the stomach is composed of the following layers:

(1) A delicate internal cuticle.

(2) A single layer of large cylindrical or cubical epithelial cells with large nuclei; their condition varies with the state of distension of the stomach.

(3) An elastic basement membrane.

(4) Muscular fibres, circular and longitudinal, forming a loose network.

In this last layer there are numerous air-tubes or tracheæ, which probably help to keep the gut in position in the cœlom.

7-10. *Hind-Gut.*—This runs from the end of the mid-gut to the anus, being divided into the following regions:

(1) A dorsally bent portion, the ileum, lined by flattened epithelium.

(2) A ventrally bent portion, the colon, lined by cubical epithelium.

(3) A dilated portion, the rectum, which has six large ovoid papillæ.

The rectum narrows just before the anus, which opens on the last segment of the body.

Malpighian Tubes.—There are five Malpighian tubes opening at the junction of the mid- and hind-gut.

Salivary Glands.—The salivary glands consist of two groups, each containing three acini, lying on each side of the body, in the anterior portion of the thorax, close against the prosternum, and extending almost as far back as the proventriculus. The ducts from each of these acini unite together to form a single duct on each side, which passes forwards through the neck into the head, where it unites beneath the subœsophageal ganglion, with its fellow of the opposite side, to form a common salivary duct. This duct passes forwards to end in the salivary pump, which is continuous with the salivary groove or canal of the hypopharynx. The duct of the salivary gland, therefore, is not in any way connected with the alimentary canal. These glands, which are much larger in the female than in the male, are composed of acini, surrounded by a basement membrane which is very delicate and structureless, and upon which rests a single layer of epithelial cells surrounding a central lumen. The whole acinus lies in a cleft in the fat-body.

Space does not permit of descriptions of the vascular, nervous, and muscular systems being included.

Reproductive Organs.—The female reproductive organs consists of ovaries, oviducts, and a common oviduct, a mucous gland and its duct, and a spermatheca and duct, while the male organs are testes and vasa deferentia, which, after receiving the ducts of the receptacula seminis, run to an ejaculatory duct, which ends in a short penis.

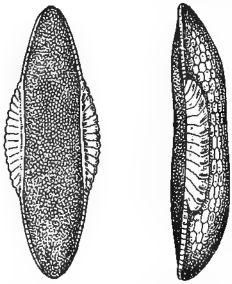


FIG. 221.—EGG OF ANOPHELES MACULIPENNIS.

(After Nuttall and Shipley.)

On the left the egg is seen from above, and on the right from the side.

Life-History. — A mosquito passes through a complicated life-cycle, consisting of an egg, a larval, and a pupal stage, the last-named giving rise to the perfect insect or imago.

Soon after a female insect is hatched it probably becomes fertilized, though some authorities believe that this does not take place until after the first meal of blood, which in any case precedes the oviposition, which takes place in the early morning.

The eggs, which number about one hundred, are laid upon the surface of the water, on which they may be seen arranged in stars, rows, or triangles.

The eggs of *A. maculipennis* are boat-shaped, about 0·5 to 1 millimetre in length, with a flat upper and convex lower surface, and with one end somewhat broader than the other. The head of the larva will be found at this broader anterior end. The upper surface is granular and reticulated, while the lower is smooth. On each side of the middle third the chitinous capsule is thrown into folds, called floats, while the margin projects as a chitinous frill.

The duration of the egg stage has not been well defined. Nuttall and Shipley give two to three days for *Anopheles maculipennis*, but it is probable that it is shorter in the tropics. The appearance and grouping of the eggs are quite different in the Culicinæ, as will be mentioned later.

The larva escaping from the blunt anterior end of the egg by the shifting off of a piece like a cap from the rest of the shell is seen to consist of head, neck, and abdomen.

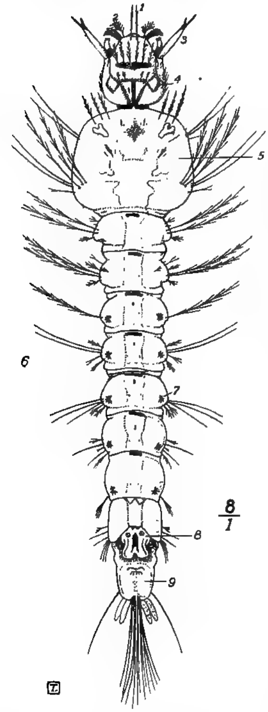


FIG. 222.—LARVA OF ANOPHELES MACULIPENNIS.

(After Nuttall and Shipley, *Journal of Hygiene.*)

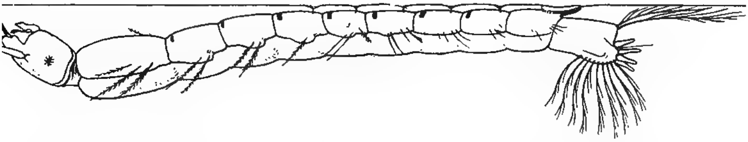
1, Internal clypeal hairs; 2, external clypeal hairs; 3, antennæ; 4, head markings; 5, thorax; 6, abdomen; 7, palmate hair; 8, stigmatic siphon; 9, last segment.

When first hatched the head is very black, but later on it becomes lighter in colour, and shows characteristic markings. At the back of the head there is a little notch, and from this a **V**-shaped dark line opens forwards, formed by two diverging bands of chitin, arranged along which are patches of pigment, which give rise to the characteristic markings. There are two large compound eyes, behind each of which lies a single eye-spot, or ocellus.

The antennæ are conspicuous rod-like bodies ending in two leaf-shaped appendages, between which is a branched hair, while another hair of specific importance arises from a papilla situated at the junction of the proximal and middle thirds.

Between the roots of the antenna and projecting forwards there is a smooth, shield-like area, the clypeus, which carries four or six hairs, which are also of specific importance. Two of these hairs (internal clypeal hairs) arise anteriorly near the middle line; external to these lie the external clypeal hairs, which arise from the outer angle of the clypeus; and behind them lie the posterior clypeal hairs. Sometimes there is a basal hair external to the antennæ.

he mouth parts consist of two large feeding-brushes, two maxillary palps, mandibles, and on the ventral median line the under lip of Meinert, a cal chitinous structure, and a snout-like process covered with hairs pro- ing between the brushes.



IG. 223.—Larva of an Anopheline Mosquito lying Parallel to the Water.

(Modified after Howard.)

he thorax is large, increasing in size as the larva grows older. It has nerous hairs, and sometimes a pair of the palmate hairs presently to be cribed.

here are nine segments in the abdomen, of which the eighth is characterized possessing the openings of the tracheæ, and the ninth by possessing four

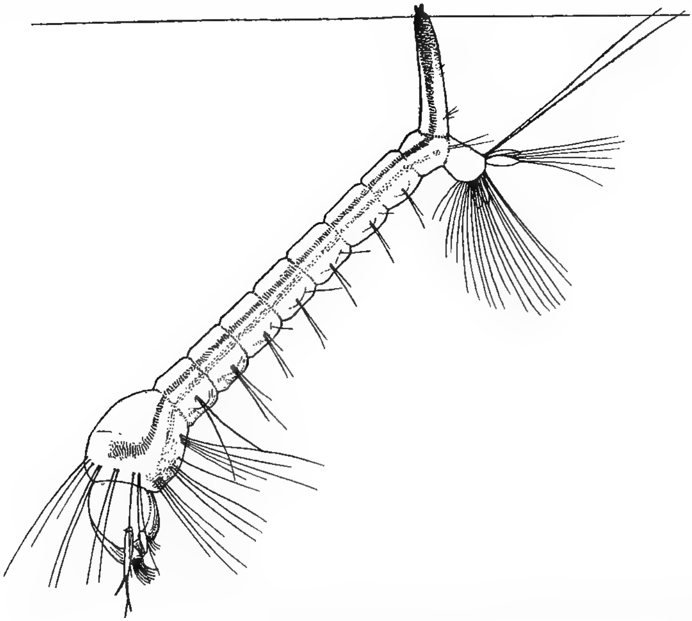


Fig. 224.—Larva of a Culicæ Mosquito, hanging down from the Surface of the Water.

(After Howard.)

rge papillæ, and hairs projecting downwards and backwards. The first two gments possess a pair of large feathered hairs on each side, the third a single air on each side. The others do not possess these hairs. Certain of the dominal segments have small, fan-shaped hairs, called ' palmate hairs,' fixed by a short stalk on the outer side of the dorsum of the segment. Each of thes consists of nineteen to twenty leaflets, which are capable of closing and openin upon the stalk like a fan. These hairs are rudimentary in the freshly hatche larva, but in the adult they are well marked, and have been used for purpose of classification, according to the variations in their number and position, an the character of the leaflets and their terminal hairs, if present. These hair are of use in helping to keep the larva in its horizontal position when i comes up to breathe on the surface of the water.

The stigmatic siphon is placed, as already mentioned, on the eighth segment, forming by means of raised, toothed, chitinous processes a quadrilatera space.

The teeth are of great importance, being capable of being approximated s as to close the cavity, and thus protect the two openings of the tracheæ whic lie in the anterior portion of the siphon. From these openings the lon tracheæ can be seen running from back to front along the larva.

The duration of the larval stage varies with food and temperature, being longer in the temperate zone than in the tropics According to Stephens, it i twelve days in *Cellia argyrotarsi* and eleven days in *Mysomia rossii*, while it may be eightee to twenty-one days in *Anophele maculipennis* in the temperat zone. The larva grows by moulting several times.

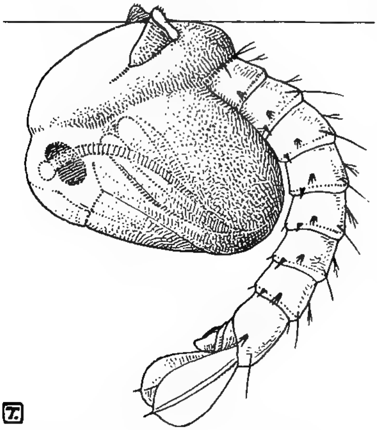


FIG. 225.—PUPA OF ANOPHELES MACULIPENNIS.

(After Nuttall and Shipley, *Journal of Hygiene.*)

Culicine larvæ are easily distinguished from Anopheline larvæ by the fact that the spiracles are carried on a long respiratory siphon, formed by a prolongation of the dorsum of the eighth abdominal segment, which has been used to distinguish the different species.

Below the siphon on the eighth segment there are spines, forming a comb, while along the length o the siphon there is another comb, distal to which is a tuft of hairs The variations in these structures, together with those in the length and breadth of the siphon, associated with those of the antennæ and clypeus, afford means of classifying the Culicine larvæ For further information, consult either Theobald's Monograph, vol. iv., p. 6, or Felt's paper, Bulletin 97 of the Division o Entomology of the New York State Museum. The Megarhininæ, Ædinæ, and Uranotæninæ possess larvæ belonging to the Culicine type.

The pupal stage lasts about forty-eight hours. Towards the en of an afternoon the pupa comes up to the surface, and the dorsa portion of the thorax splits with a T-shaped fissure, and the adul insect or imago emerges. Pupæ do not eat.

Differences between the Anophelinæ and Culicinæ.—The difference between these two important families may popularly be described as follows:

The Anophelinæ, as a rule, project from any plane surface on which they may be resting at a sharply defined angle, owing to their head, thorax, and abdomen forming a more or less straight line; while the Culicinæ, on the other hand, do not make such a well-defined angle, owing to the fact that the abdomen is not in the same straight line as the long axis of the thorax. The eggs of the Anophelinæ are laid singly, while those of the Culicinæ are laid in rafts. The larvæ of the Anophelinæ have no drawn-out siphons, and therefore lie more or less parallel to the surface of the water, while the larvæ of the *Culicinæ* hang downwards. There are, however, exceptions to these rules—thus, *e.g.*, *Myzomia culicifacies* rests on a surface like a *Culex*, not like an *Anopheles*.

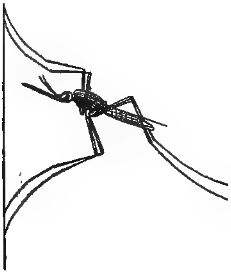


FIG. 226.—DIAGRAM TO SHOW THE POSTURE OF AN ANOPHELINE MOSQUITO ON A WALL.

(After Sambon, from the *British Medical Journal*.)

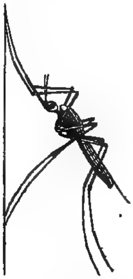


FIG. 227.—DIAGRAM TO SHOW THE POSTURE OF ANOTHER ANOPHELINE MOSQUITO ON A WALL.

(After Sambon.)

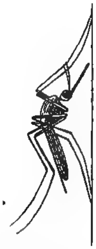


FIG. 228.—DIAGRAM TO SHOW THE POSTURE OF CULEX PIPIENS ON A WALL.

(After Sambon.)

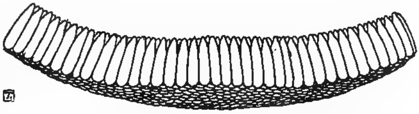


FIG. 229.—RAFT OF CULICINE EGGS.

(After Sambon.)

Bionomics.—The imago emerges from the pupa during the late afternoon, after which the females are ready for fertilization by the males. These latter can sometimes be seen in large numbers, while but few females are observed, which is supposed to be characteristic of the breeding period.

The female alone bites man and animals, apparently for the purpose of obtaining rich food for the eggs, while the male feeds on the juices of plants and fruits. The female can also be seen feeding upon vegetable juices, though this is more common in the females of the Culicinæ than in those of the Anophelinæ. It is believed that a female feeds on blood once a day in nature, but this is a difficult matter to be certain about. The mechanism of the bite has already been described in Chapter VIII., to which reference should be made. It will also be noted that the structure of the female mouth parts is adapted for piercing, while that of the male is not. It will also be remembered that only the stylets pierce the skin, and that the labium never does so. Infection of the victim by the malarial germ takes place during the act of biting, as the sporozoites pass down the hypopharyngeal or salivary tube, while the infection of the mosquito is effected by the blood, which passes from the victim along the labial or blood-tube into the mouth. So much blood may be sucked that it may appear *per anum*.

Usually the mosquitoes bite at night, and preferably in the dark, as, for example, they will attack the ankles of people while sitting at dinner at night.

After feeding, the mosquitoes usually retire to a dark portion of the room to digest the food. It is noticeable that they avoid white areas during the day-time, and prefer dark-coloured regions away from the light, and hence are very difficult to find in ill-lighted native huts.

In the early morning the female flies to the nearest water and lays her eggs. Usually she does not travel far, but is believed to be capable of going at least half a mile in case of need.

The females of the Culicinæ do not appear to concern themselves as to the nature of the water in which they lay their eggs, but the female Anophelinæ prefer clean water with a certain amount of weed. This water may be the back eddies of a river, where there is the protection of weeds, or the margins of large lakes, where dense surface vegetation is to be found, or any collection of water which contains green vegetal matter, or, failing these, any collection of fresh or moderately salt water. Small and large wells are a prolific source of mosquitoes, as are puddles, and water in broken bottles, shells, and especially in plants like bamboos, etc. Having laid the eggs, they retire to some dark corner during the daylight, and emerge at night for another feed of blood. How long they live is not known with certainty, and will be discussed, together with other features of their bionomics, in Chapter XXIII., under Malaria.

Mosquitoes can hibernate during the cold weather of the temperate zone, and æstivate during the dry hot weather of the tropics. In this latter condition they bite and suck blood, but apparently do not lay eggs, even if water is provided. The eggs are kept afloat on the surface of the water by their structure, and in due course give rise to the larvæ, which are great eaters, living not merely upon unicellular organisms, such as algæ and diatoms, but also upon their fellows. For purposes of obtaining air they are compelled to come to the surface of the water. The Anopheline larva, not possessing a siphon, has to lie more or less parallel with the surface of the water in order to enable the air to enter the spiracles, and this it is able to do by the aid of the palmate hairs already mentioned; while the Culicine larvæ have merely to bring the apex of the siphon to the surface of the water, from which they apparently hang downwards. Larvæ are certainly able to hibernate, and perhaps eggs also. The pupa does not feed.

Mosquitoes have many enemies and parasites, but the most important from a point of view of the prophylaxis of malaria are those which eat the eggs, the larvæ, and the pupæ, of which fish are the most important.

In 1905 C. K. Gibbons pointed out that a small fish, popularly termed 'millions,' which lived in shallow water, was a voracious feeder on eggs, larvæ, and pupæ of mosquitoes. These fish, which belong to the species *Girardinus pœciloides* de Filippi, are found in Barbadoes, which is very free from malaria. They are very small, the full-grown female only measuring 1½ inches in length, while the male is smaller. The female is dull in colour, while the male is distinguished by red splashes and a black circular dot on its sides. The great importance of these little fish is that they are able to live in very shallow water, and to work their way in among dense surface vegetation, and thus to gain access to the larvæ, etc., of the mosquitoes, which otherwise are protected by the weeds from attacks by the larger fish. There is no doubt that these small fish should be introduced into malarious places as a prophylactic measure against the disease. Other closely allied species are *G. versicolor* Günther, found in St. Domingo, and *G. formosus*, found in Florida and South Carolina. With regard to other species, *Gambusea molliensia* is said to be of great value in consuming larvæ, especially when protected by dense surface vegetation.

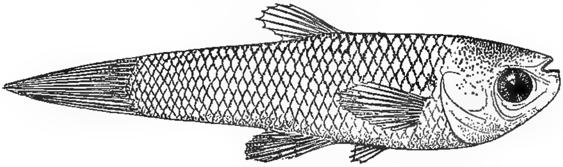


FIG. 230.—GIRARDINUS PŒCILOIDES DE FILIPPI.

(The tail should have been expanded.)

Certain plants, as is well known, collect water, especially the bromelias, the bamboos, and the pitcher-plants. In this water Culicine and sometimes Anopheline larvæ can be found. E. E. Green, of Ceylon, has shown that the flowers of the lobster-claw plant (*Heliconea brasiliensis*) can hold a considerable amount of water, in which he found Stegomyia and Desvoidea larvæ in large numbers.

Classification.—Various methods of classifying mosquitoes have been brought forward. The earliest were based upon the characters of the palpi, but in 1901 Theobald showed that they were useless for anything but specific characteristics, and based his larger divisions on the variations of the scales on the head, body, and wings. Felt brought forward a classification based upon the male genitalia and the wing veins, but, as Theobald remarks, the majority of known mosquitoes being female, it is most undesirable to take only male characters for the classification. Recently Dyar and Knab have issued a classification of the Culicidæ by larval characters, and Eysell has advanced matters considerably by separating the Corethrinæ from the Culicidæ under the term Corethridæ, because the Corethridæ have an entire absence of the long piercing proboscis and of scales in the adults, both of which are marked features of the Culicidæ. It will be evident that this is useful. Lutz has brought forward a classification based upon larval and adult forms, which Theobald has modified and brought into accord with one based upon scales as generic characters, and this classification is followed below.

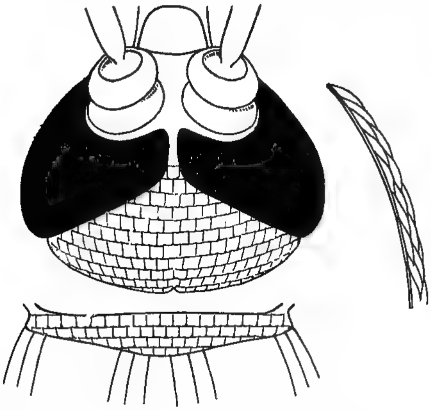


FIG. 231.—HEAD AND SCUTELLUM OF MEGARHINUS, TO SHOW THE SCALES.
On the left a profile view of the scales.
(After Theobald, 'Culicidæ of the World.')

THEOBALD'S CLASSIFICATION.—The Culicidæ may be divided into subfamilies, according to the characters of the scales on the head, body, legs, and wings.

- A. Scutellum simple, never trilobed; proboscis straight; palpi long in male and female—Anophelinæ.
- B. Scutellum trilobed:
  - I. Proboscis strongly recurved; first submarginal cell very small—Megarhininæ.
  - II. Proboscis straight; post-scutellum nude:
    - 1. Wings with six longitudinal scaled veins:
      - (1) Antennæ with second joint normal in length:
        - (*a*) First submarginal cell as long as or longer than the second posterior cell.
          - Palpi in the female shorter than the proboscis; long in male—Culicinæ.
          - Palpi short in both sexes—Ædinæ.
        - (*b*) First submarginal cell very small; smaller than second posterior—Uranotæninæ.
      - (2) Antennæ with second joint very long—Deinoceratinæ.

2. Wings with seven longitudinal scaled veins—Heptaphlebomyinæ.

III. Proboscis straight; post-scutellum with scales or chætæ:
   1. Palpi long in male, short in female—Trichoprosoponinæ.
   2. Palpi short in both sexes—Dendromyinæ.

IV. Proboscis elbowed—Limatinæ.

Of these, only the Anophelinæ and the Culicinæ, and possibly the Ædinæ, contain species of importance in tropical medicine, and concerning these subfamilies a few details must be given.

ANOPHELINÆ.

Culicidæ with straight proboscis; palpi long in both sexes; occiput mostly with upright forked scales, never with flat lateral scales. Thorax with scales or hairs, scutellum never trilobed, with scales or hairs. Post-scutellum nude. Abdomen with hairs or scales. Eggs laid singly, and not in rafts. Larvæ without respiratory siphon.

This is a most important family, because it contains the species which are known to carry malaria. The list of known carriers, as given by Theobald, is as follows: *Anopheles maculipennis* Meigen, Europe and North America; *A. bifurcatus* Linnæus, Europe; *Myzomia listoni* Liston, India; *M. culicifacies* Giles, India; *M. funesta* Giles, West Africa; *M. superpicta* Grassi, Italy; *Myzorhynchus paludis* Theobald, West Africa; *M. barbirostris* van der Wulp, Asia; *M. pseudopictus* Grassi, Italy; *M. sinensis* Wiedemann; *M. coustani* Laveran, Madagascar; *Pyretophorus costalis* Loew, West Africa; *Nyssorhynchus lutzi* Theobald, Brazil; *N. theobaldi* Giles; *N. stephensi* Liston; *Cellia argyrotarsis* Robineau-Desvoidy; *C. albimanus* Wiedemann.

It is also certain that malaria is carried by *Anopheles martini* Laveran from Cambodie, *A. pursati* Laveran from Cambodie, *A. vincenti* Laveran from Tonkin; but the position of these mosquitoes in Theobald's classification has not been determined.

It appears probable that the following are also malarial carriers: *Myzomia turkhudi* Liston, *Pyretophorus ardensis* Theobald, *P. pitchfordi* Power.

It is extremely doubtful whether *Myzomia rossii* ever spreads malaria.

Filariasis is spread by *Pyretophorus costalis* Loew, *Myzomia rossii* Giles, *Myzorhynchus nigerrimus* Giles, *M. minutus* Theobald, *Mansonia uniformis* Theobald, *M. pseudotitillans* Theobald, *Cellia albimanis*.

Filaria can live in *Anopheles maculipennis*, *A. annulipes*, *Myzomia funesta*.

It is, therefore, important for the student of tropical medicine to be able to recognize the genera and species of the more important Anophelinæ. For this purpose we give the following tables taken from Theobald's 'Manual of the Culicidæ,' vol. iv., 1907; but for fuller information the original work must be consulted.

SUBFAMILY ANOPHELINÆ Theobald 1901.

Table of Genera.

- A. First submarginal cell very small—*Birónella* Theobald.
- B. First submarginal cell large :
  - I. Antennal segments with dense lateral scale-tufts—*Chagasia* Cruz.
  - II. Antennal segments without dense lateral scale-tufts :
    - 1. Thorax and abdomen with hair-like curved scales :
      - (*a*) No flat scales on head, but upright forked ones.
        - (α) Basal lobe of male genitalia of one segment.
          - (1) Wing scales large, lanceolate—*Anopheles* Meigen.
          - (2) Wing scales mostly small, long, and narrow, or slightly lanceolate—*Myzomia* Blanchard.
          - (3) Wings with patches of large inflated scales—*Cycloleppteron* Theobald.
        - (β) Basal lobe of two segments :
          - Prothoracic lobes with dense outstanding scales—*Feltinella* Theobald.
      - (*b*) Median area of head with some flat scales ; prothoracic lobes mammillated. Wing scales lanceolate—*Stethomyia* Theobald.
    - 2. Thorax with narrow curved scales ; abdomen hairy :
      - (*a*) Wing scales small and lanceolate; head with normal forked scales—*Pyretophorus* Blanchard.
      - (*b*) Wing scales broad and lanceolate ; head with broad scales, not closely appressed, but not forked or fimbriated—*Myzorhynchella* Theobald.
    - 3. Thorax with hair-like, curved scales, and some narrow curved ones in front; abdomen with apical lateral scale-tufts and scaly venter; no ventral tuft. Wing scales lanceolate—*Arribalzagia* Theobald.
    - 4. Thorax with hair-like, curved scales; no lateral abdominal tufts ; distinct apical ventral tuft. Palpi densely scaly. Wing with dense, large, lanceolate scales—*Myzorhynchus* Blanchard.
    - 5. Thorax with hair-like, curved scales, and some narrow, curved lateral ones ; abdomen hairy, with dense long, hair-like, lateral apical, scaly tufts. Wing scales short, dense, lanceolate; fork cells short—*Christya* Theobald.
    - 6. Thorax with very long, hair-like, curved scales ; abdomen with hairs, except last two segments, which are scaly. Dense scale-tufts to hind femora. Wings with broadish, blunt, lanceolate scales—*Lophoscelomyia* Theobald.
    - 7. Thorax and abdomen with scales :
      - (*a*) Thoracic scales narrow-curved or spindle-shaped ; abdominal scales as lateral tufts and small dorsal patches of flat scales—*Nyssorhynchus* Blanchard.
      - (*b*) Abdomen nearly completely scaled, with long, irregular scales, and with lateral scale-tufts—*Cellia* Theobald.
      - (*c*) Similar to above, but no lateral scale-tufts—*Neocellia* Theobald.
      - (*d*) Abdomen completely scaled with large flat scales, as in *Culex*—*Aldrichia* Theobald.
      - (*e*) Thoracic scales hair-like, except a few narrow-curved ones in front ; abdominal scales long, broad, and irregular—*Kertészia* Theobald.

Anopheles Meigen 1818.

Essentially *Anopheles* are temperate zone or hill-station Anophelinæ, of which the type *Anopheles maculipennis* Meigen 1818 has been already described.

Sixteen species are definitely known, but in addition there are the uncertain species of *A. ferruginiensis* Wiedemann, *A. martini* Laveran, *A. pursati* Laveran, *A. vincenti* Laveran, etc.

Theobald gives the following table by means of which the species may be recognized.

ANOPHELES.

- A. Wings spotted :
  - I. Legs unbanded :
    - 1. Wings with spots formed of collections of scales on the wing field ; no costal spots—*maculipennis* Meigen.
    - 2. Wings with light and dark costal markings. Costa with two yellow spots :
      - (*a*) Large species :
        - (α) No fringe-spots—*punctipennis* Say.
        - (β) Fringe-spots present—*pseudopunctipennis* Theobald.
      - (*b*) Small species. Wings much spotted — *franciscanus* McCracken.
  - II. Legs with basal pale bands.
    Costa with two large dark spots—*gigas* Giles.
  - III. Legs with narrow apical bands.
    Costa dark, with two small pale yellow spots — *wellcomei* Theobald.
- B. Wings unspotted :
  - I. Legs unbanded :
    - 1. Thorax adorned as in Corethra—*corethroides* Theobald.
    - 2. Thorax normal ornamentation.
      - (*a*) Second fork cell much more than half the length of the first.
        - (1) Palpi unbanded.
          - (α) Petiole of first fork cell more than one-third length of cell.
            Abdomen with golden hairs—*bifurcatus* Linnæus.
            Abdomen with brown hairs—*algeriensis* Theobald.
          - (β) Petiole of first fork cell one-third length of cell—*barberi* Coquillett.
        - (2) Palpi banded. Dark species. Wing-scales very dense—*smithii* Theobald.
          Wing-scales not so dense—*nigripes* Staeger.
      - (*b*) Second fork cell not more than half the length of the first—*aitkenii* Theobald.
  - II. Legs banded :
    - 1. Hind femora only with broad white band—*lindsayii* Giles.
    - 2. Apices of hind tarsi pale—*immaculatus* Theobald.
    - 3. Position uncertain—*eiseni* Coquillett.

Myzomyia Blanchard 1902.

This *Myzomyia* includes some important mosquitoes found in West Africa, and in India and Ceylon, which are carriers of malaria.

The diagnostic table given by Theobald is as follows :

MYZOMYIA.

- A. Proboscis unbanded :
  - 1. Legs banded :
    - (*a*) Palpi with three white rings.
      - (1) Legs with faint apical pale bands.
        Wing-fringe spotted—*funesta* Giles.
      - (2) Legs with prominent apical pale bands, and a broad, pale, median band to fore and mid metatarsi—*lutzii* Theobald.
      - (3) Legs (hind) with apical and basal pale bands.
        Wings with five to six pale costal spots, the largest **T**-shaped—*rossii* Giles.

Wings with three yellow costal spots—*longipalpis* Theobald.
(*b*) Palpi with two white rings—*aconita* Dönitz.
2. Legs spotted and banded.
(*a*) Supernumerary cross-vein straight.
(α) Palpi with three white bands. Apical and basal pale leg banding.
(1) Third large costal spot with two spots beneath on first vein—*ludlowii* Theobald.
(2) Third costal spot T-shaped, as in *Rossii*—*indefinata* Ludlow.
(3) Thorax with two ocelli; wings much spotted—*tessellata* Theobald.
(β) Palpi with four white bands—*elegans* James.
(*b*) Supernumerary cross-vein markedly curved—*pyretophoroides* Theobald.
3. Legs unbanded:
(*a*) Apex of palpi white and ringed. Three pale palpal bands.
(α) Third long vein mostly yellow—*listoni* Liston.
(β) Third long vein dark.
(1) Several fringe-spots—*leptomeres* Theobald.
(2) Two fringe-spots—*culicifacies* Giles.
(3) No fringe-spots—*rhodesiensis* Theobald.
(*b*) Apex of palpi white only—*nili* Theobald.
(*c*) Apex of palpi black.
(1) Black apex narrow—*turkhudi* Liston.
(2) Black apex broad—*hispaniola* Theobald.
B. Proboscis banded:
I. Legs unspotted—*albirostris* Theobald.
II. Legs spotted—*thorntonii* Ludlow.

Pyretophorus Blanchard 1902.

The important species is *Pyretophorus costalis*, the spreader of malaria in West Africa and Mauritius.

PYRETOPHORUS.

A. Legs unbanded:
I. Palpi with three pale bands; apex black — *nigrifasciatus* Theobald.
II. Palpi with three pale bands; apex white:
(*a*) Wings with four large and two small black costal spots; mid cross-vein very long—*nursei* Theobald.
(*b*) Wings with four large black spots; mid cross-vein normal —*minimus* Theobald.
(*c*) Wings with five large black costal spots:
(1) First fork cell much longer than the second posterior—*sergentii* Theobald.
(2) First fork cell about as long as the second cell—*palestinensis* Theobald.
B. Legs banded:
I. Legs with apical banding. Hind-legs only banded. Palpi, black apex, and three pale bands.
(*a*) Three dark lines on post-scutellum—*myzomyfacies* Theobald.
(*b*) Two dark lines on post-scutellum—*chaudoyei* Theobald.
II. All legs with apical pale bands. Palpi with three white bands.
(*a*) Wings with four black costal spots; fringe unspotted—*superpictus* Grassi.
(*b*) Wings with four large and two small costal spots; fringe spotted.
(α) Apical palpal band broad; other two small—*jeyporensis* Theobald.

(β) Apical and median palpal bands broad—*austenii* Theobald.
III. Fore and hind legs with apical pale bands.
Four white papal bands—*cinereus* Theobald.
C. Legs spotted and banded :
I. Last three hind tarsals all white.
Thorax golden scaled—*aureosquamiger* Theobald.
II. Last hind tarsal not white :
(*a*) Femora and tibiæ spotted. Tarsal bands apical. Three palpal bands.
(α) Apical one broad ; others narrow—*costalis* Loew.
(β) Apical and median ones broad—*marshallii* Theobald.
(*b*) Femora, tibiæ, and first tarsals spotted. Tarsal bands apical. Four palpal bands—*ardensis* Theobald.
(*c*) A broad tibio-metatarsal joint band.
(α) Mid-legs banded—*elegans* James.
(β) Mid-legs unbanded—*leucosphyrus* Dönitz.

Myzorhynchus Blanchard 1902.

These mosquitoes are usually said to only occur in the open, but we have repeatedly found *Myzorhynchus barbirostris* in houses. *M. sinensis* is known to carry the parasite of malaria in Japan. No species have so far been reported from America.

The sixteen species can be recognized as follows (recently it has been asserted that *Anopheles constani*, which has never been correctly placed, is *M. constani* Laveran) :

MYZORHYNCHUS.

A. Palpi unbanded :
I. Last hind tarsals brown :
Legs with pale apical tarsal bands :
(*a*) One fringe-spot.
(1) Legs not spotted—*barbirostris* van der Wulp.
(2) Legs with speckled femora and tibiæ, and more numerous 'round-ended' scales on the wing—*pseudobarbirostris* Ludlow.
(*b*) Several fringe-spots—*bancroftii* Giles.
(*c*) No fringe-spot.
(1) One pale costal spot ; wings with light and dark scales—*umbrosus* Theobald.
(2) Two pale costal spots ; wings mostly dark-scaled—*strachanii* Theobald.
II. Last hind tarsal white—*albotæniatus* Theobald.

B. Palpi banded :
I. Last hind tarsal brown :
(*a*) Wing-fringe with one pale spot—*sinensis* Wiedemann.
(*b*) Wing-fringe unspotted.
(α) Palpi with four pale bands ; apex white.
1. Wings with two yellow costal spots.
(1) Wings distinctly spotted—*vanus* Walker.
(2) Wings without prominent spots—*pseudopictus* Grassi.
2. Wings with two white costal spots — *minutus* Theobald.
(β) Apex of palpi black—*nigerrimus* Giles.
II. Last two hind tarsals white—*mauritianus* Grandpré.
III. Last three hind tarsals white—*paludis* Theobald.

Nyssorhynchus Blanchard 1902.

The important member is *Nyssorhynchus fuliginosus* Giles 1900, which is without doubt a malarial carrier. Theobald's diagnostic table is as follows :

NYSSORHYNCHUS.

A. Last hind tarsals brown :
  Legs spotted :
    (*a*) Apical pale bands to legs.
      (1) Proboscis dark—*stephensi* Liston.
      (2) Proboscis pale on apical half—*masteri* Skuse.
    (*b*) Apical and basal pale banding—*annulipes* Walker.

B. Last hind tarsal white :
  I. Legs spotted with white :
    (*a*) Palpi with three white bands—*willmori* James.
    (*b*) Palpi with four white bands—*maculatus* Theobald.
  II. Legs not spotted ; four palpal bands—*karwari* James.

C. Last two hind tarsals white. Legs with mottled femora, tibiæ, and tarsi ; three white palpal bands :
    (*a*) Two apical palpal bands close together—*theobaldi* Giles.
    (*b*) Two apical palpal bands far apart—*pretoriensis* Theobald.

D. Last three hind tarsals white :
  I. Palpi with three white bands :
    (*a*) Palpi spotted ; legs spotted—*maculipalpis* Giles.
    (*b*) Palpi not spotted ; legs spotted—*jamesii* Theobald.
    (*c*) Palpi and legs not spotted.
      (1) Wings with four white costal spots—*fuliginosus* Giles.
      (2) Wings with five white costal spots—*nivipes* Theobald.
  II. Palpi with four white bands—*philippinensis* Ludlow.

Cellia Theobald 1902.

This genus, which is widely distributed throughout the tropics, has two malarial carriers, *Cellia argyrotarsis* and *C. albimana*, the latter being also known as a filarial carrier.

CELLIA.

A. Legs with last three hind tarsals white :
  I. Dark species—*argyrotarsis* Robineau-Desvoidy.
  II. Yellowish species—*pulcherrima* Theobald.

B. Legs with last hind tarsals white :
  I. Femora and tibiæ mottled ; apical foot-bands—*pharoensis* Theobald.
  II. Femora and tibiæ not mottled—*bigotii* Theobald.

C. Legs with last hind tarsal white, except base ; second and third white—*albimana* Wiedemann.

D. Legs with last hind tarsal dark.
  I. Dark species ; three white long lateral thoracic lines—*squamosa* Theobald.
  II. Pale species ; thorax with two eye-like spots ; pleuræ pale with large black spots—*kochii* Dönitz.

SUBFAMILY CULICINÆ Theobald 1901.

Culicidæ with straight proboscis, long palpi in the male, short in the female. Post-scutellum nude ; wings with a long first submarginal cell, and without a third anal vein. Larvæ with respiratory siphons.

There are upwards of sixty-three known genera, but of these only *Stegomyia*, *Culex*, and perhaps *Mansonia*, are of importance to medical men at present.

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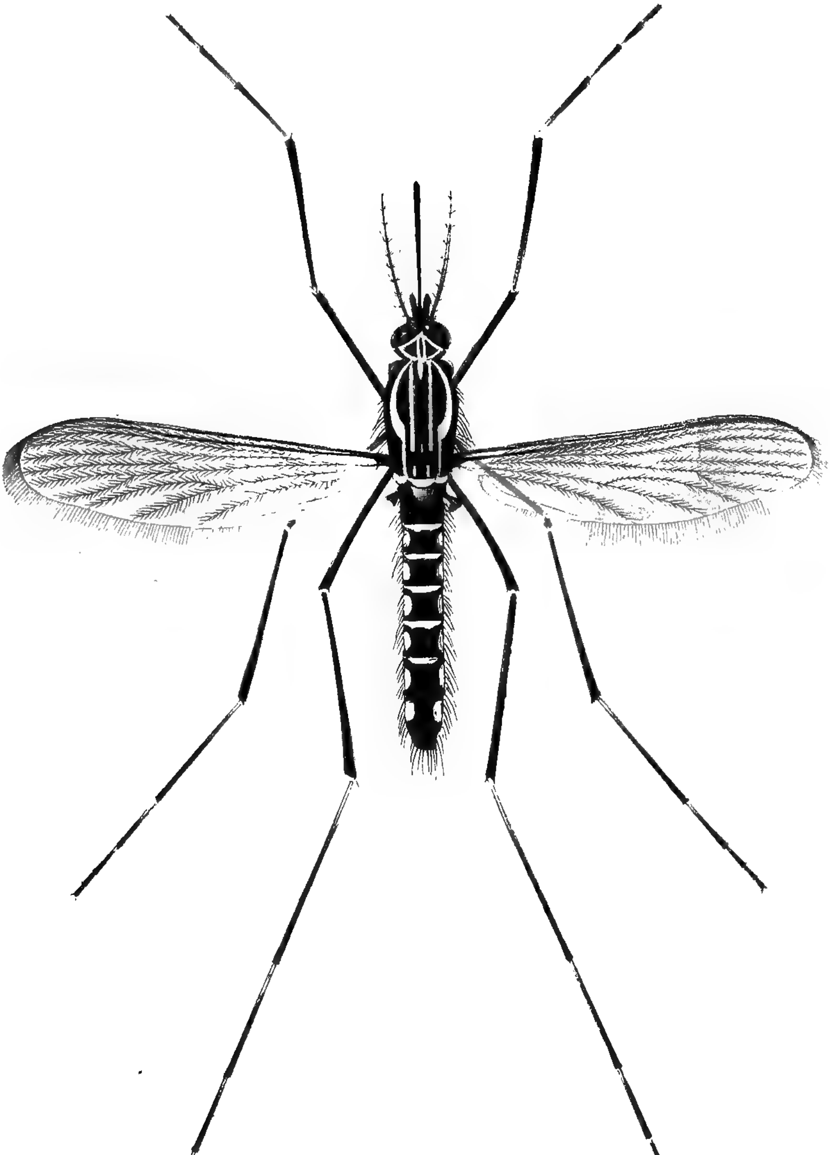

STEGOMYIA CALOPUS MEIGEN.

FEMALE.

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STEGOMYIA Theobald 1901.

Culicinæ with the head and scutellum clothed with flat scales.

The important species is *Stegomyia fasciata*, the tiger mosquito, which spreads yellow fever. It is peculiar in that it bites chiefly in the afternoon. It is found all over the world, which is due to the fact that it can live on board ship easily.

Unfortunately its name is about to be changed either to *S. calopus* Meigen, or *S. frater* Desvoidy. Theobald at present is not certain which will prove to be the correct term. The name as it stands at present is *S. fasciata* Fabricius 1805 (*non* Villiers 1789) (synonyms: *Culex calopus* Meigen 1818(?), *C. frater* Desvoidy 1827). Villiers, it appears, used the term 'fasciata' for a *Culex* in 1789.

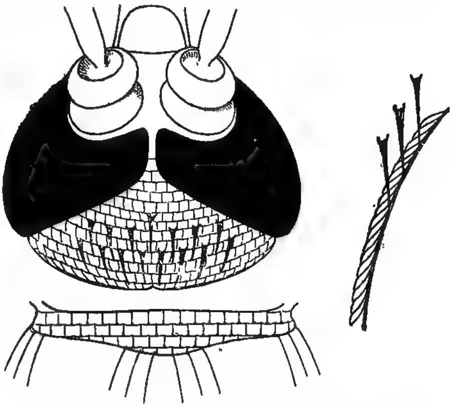

FIG. 232.—HEAD AND SCUTELLUM OF STEGOMYIA, TO SHOW SCALES.

(After Theobald, 'Culicidæ of the World.')

STEGOMYIA.

A. Proboscis banded:
  I. Legs basally banded:
    (*a*) Thorax brown, with scattered, creamy-white scales—*annulirostris* Theobald.
    (*b*) Thorax black, with narrow, curved, golden scales—*periskeleta* Giles.
  II. Legs with basal and apical banding. Fore-legs with no bands; mid with apical and basal bands on first tarsal and second tarsal; hind with basal bands.
    Thorax white in front, with a brown eye-like spot on each side—*thomsoni* Theobald.

B. Proboscis unbanded:
  I. Legs basally banded:
    (*a*) Abdomen basally banded.
      (α) Thorax with one median silvery white line—*scutellaris* Walker.
      (β) Thorax with two median yellow lines and lateral curved silvery lines—*calopus* Meigen.
      (γ) Thorax with two short median pale lines and a white patch on each side—*nigeria* Theobald.
      (δ) Thorax with a white **W**-shaped area in front, a prolongation curved on each side enclosing a brown, eye-like spot—*W-alba* Theobald.
      (ε) Thorax with two lateral white spots, the front one the largest; a small median one near the head; two yellow median lines and a short silvery one on each side before the scutellum—*simpsoni* Theobald.
      (ζ) Thorax with a silvery white scaled area in front, and another on each side in front of wings—*argenteomaculata* Theobald.
      (η) Thorax with a median, yellowish-white line, a silvery patch on each side in front of the wings, extending as a fine yellow line to scutellum, and another silvery spot before base of each wing—*poweri* Theobald.

(*b*) Abdomen unbanded.
Third hind tarsal nearly all white. Thorax with two lateral white marks directed upwards—*africana* Theobald.

II. Legs with white lines as well as basal bands.
Thorax brown, with white lines; abdomen with basal bands—*grantii* Theobald.

III. Fore and mid-legs with apical bands; hind basal.
Fourth tarsal of hind-legs nearly all white—*mediopunctata* Theobald.

IV. Legs unbanded:
(*a*) Abdomen basally banded.
Thorax with front half silvery white, remainder bronzy-brown—*pseudonivea* Theobald.
(*b*) Abdomen unbanded.
Thorax with six silvery spots—*argenteopunctata* Theobald.
(*c*) Abdomen with apical white lateral spots.
Thorax unadorned, except for pale scaled lines laterally—*punctolateralis* Theobald.
(*d*) Abdomen with basal white lateral spots.
Thorax with two pale indistinct, median, parallel lines, and two silvery lateral spots—*minuta* Theobald.
Thorax unadorned—*amesii* Ludlow.

C. Proboscis yellow basally, dark apically.
Abdomen with apical pale bands—*crassipes* van der Wulp.

Culex Linnæus 1758.

Culicidæ with head covered with narrow, curved scales above, flat scales at the sides, and upright forked scales. Male palpi long, acuminate. Female short. Thorax with hair-like, curved scales or narrow curved scales. Linear lateral vein-scales. The important species are *Culex pipiens* Linnæus and *C. fatigans* Wiedemann.

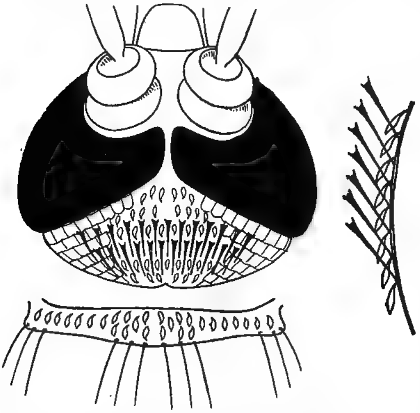

FIG. 233.—HEAD AND SCUTELLUM OF A CULICÆ MOSQUITO, TO SHOW SCALES.
(After Theobald, 'Culicidæ of the World.')

Culex pipiens Linnæus 1758.

Synonyms.—*Culex vulgaris* Linnæus 1767, *C. alpinus* Linnæus 1767, *C. agilis* Bigot, *C. ciliaris* Linnæus 1767, *C. communis* de Geer, *C. rufus* Meigen 1818, *C. phytophagus* Ficalbi 1889.

C. pipiens is widely distributed in Europe, North Africa, and North America, where it is the common brown mosquito.

Its general appearance is well shown in the illustration, in which the head is brownish from the golden-brown scales, as are the proboscis, palpi, and antennæ. The thorax is dark brown, with golden-brown curved scales, and with three black lines due to black bristles. Abdomen brown, with basal yellow bands. Legs are brown and unbanded.

Culex fatigans Wiedemann 1828.

Synonyms.—*Culex æstuans* Wiedemann 1828, *C. pungens* Wiedemann 1828, *C. pallipes* Meigen 1838, *Heteronychia dolosa* Arribalzaga 1896.

This is the common brown house-mosquito of the tropics, which is believed to spread dengue fever.

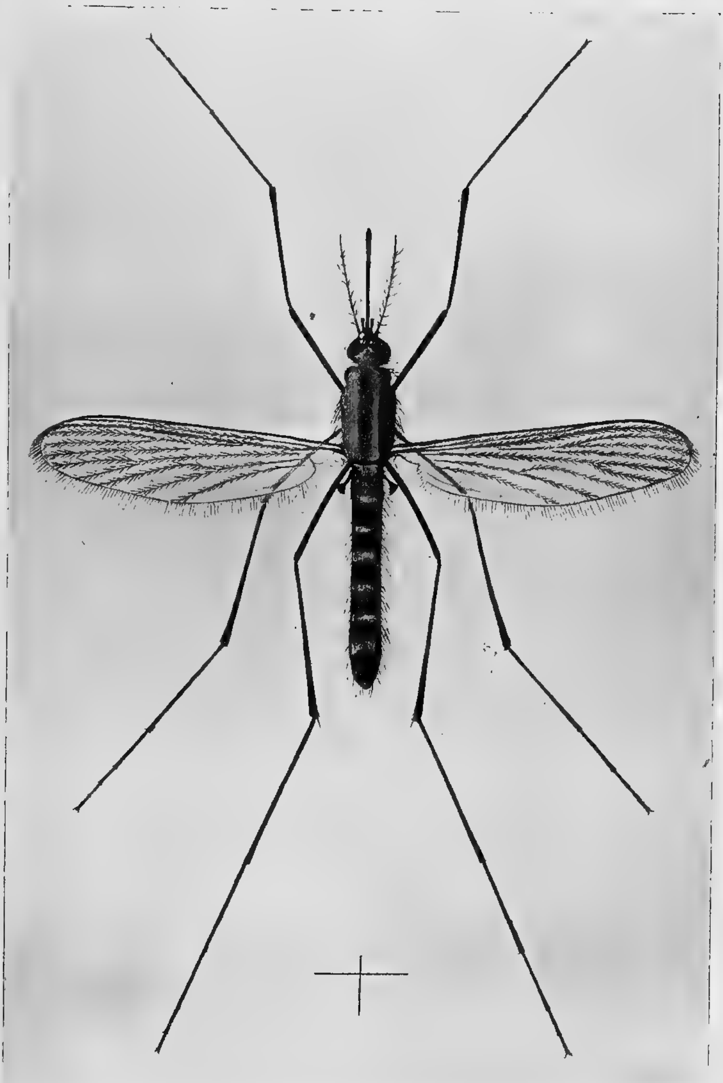

FIG. 234.—CULEX PIPIENS LINNÆUS.

It resembles the above, but has only two dark lines on the thorax as a rule, while the basal abdominal bands are white or pale cream colour, and the first fork cell is longer.

ÆDINÆ Theobald.

Culicidæ with straight proboscis, short palpi in both sexes, usually plumose antennæ in the male, pilose in the female. Wings with six scaled longitudinal veins, and with the first submarginal cell as long as or longer than the second posterior. Post-scutellum nude.

The mosquitoes included in this subfamily are generally found in the jungle, and not in habitations.

Daniels thinks that perhaps they may be proved to be malarial carriers. Loew suspects some of them (*Hæmogogus?*) as possible carriers of *Filaria* (especially *F. perstans*).

The eggs are laid in rafts, and the larvæ have respiratory syphons. A number of genera are described by Theobald, whose work should be consulted if further information is desired.

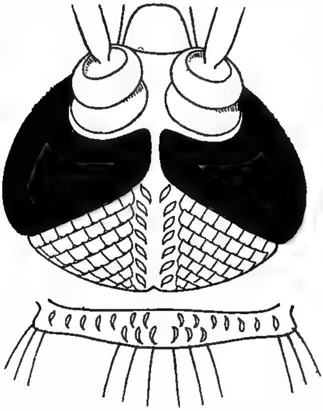

FIG. 235.—HEAD AND SCUTELLUM OF ÆDES, TO SHOW SCALES. (After Theobald, 'Culicidæ of the World.')

LIMATINÆ Theobald.

Culicidæ with elbow-bent proboscis and squamæ on post-scutellum. Palpi short in both sexes. First fork cell longer than second.

Genus.—*Limatus.*

FAMILY CORETHRIDÆ Eysell 1905.

Orthorrhapha nemocera with short proboscis not formed for piercing, without scales in the adult condition, with transparent larvæ rather resembling those of *Chironomus.*

The only reason why this family, which includes the genera *Corethra* and *Mochlonyx*, is mentioned here is that it has only recently been separated from the Culicidæ, of which it formed a subfamily—Culicimorphæ.

FAMILY CHIRONOMIDÆ.

Synonyms.—*Tipulariæ culiciformis*, *Culicites* Newman, *Tipiladæ* Leach, *Chironomii* Zelt, *Chironominæ* Roud.

Orthorrhapha nematocera with head small, often retracted under and covered by the thorax. Ocelli absent. No transverse suture on thorax; eyes reniform. Antennæ from six to fifteen joints; pectinate in male, simple and composed of fewer joints in female. Wings without veins along the posterior margin; costal vein ending near the tip of the wing.

The Chironomidæ are the midges, and have a world-wide distribution, generally being found around large sheets of water. In Ceylon they are especially abundant around the Colombo Lake. A number of genera have been recorded in addition to *Chironomus*, but only one—viz., *Culicoides* Latreille—need concern us.

SUBFAMILY CERATOPOGONINÆ.

Culicoides Latreille 1809.

Synonym.—*Ceratopogon* Meigen *Sensû latû.*

Body small, pilose, or bare. Head depressed in front, prolonged into a short rostrum. Proboscis with fleshy labium; labrum horny, seated on base of labium. Maxillæ long and horny. Antennæ thirteen-jointed, seated on a thick base; first eight joints oval, remainder elliptical, hairy. Subcostal vein ending much beyond half the length of wing; radial ending near tip; cubital ending by the tip. Abdomen composed of eight segments. Legs almost equal in length; femora armed beneath with spines.

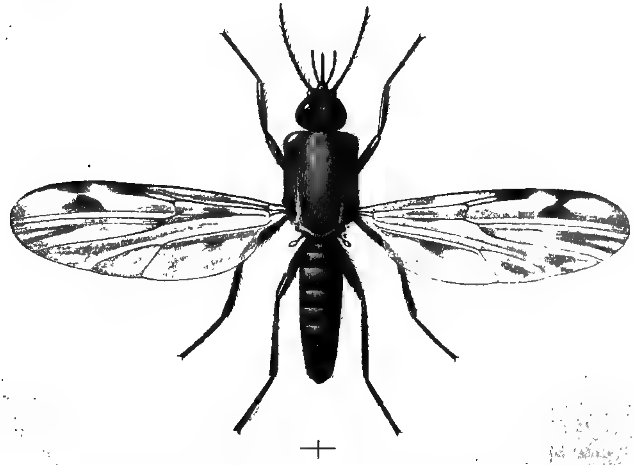

FIG. 236.—CULICOIDES PULICARIS (FEMALE).
(After Austen, 'British Blood-Sucking Flies.')

There are over one hundred known species of this genus, in which only the females suck blood, which they do most viciously, and though they are not known to cause disease, still they give rise to much irritation, especially as, being very small, they can get through any ordinary mosquito-netting. The eggs of the naked species are laid in water, attached to floating algæ, and give rise to white worm-like larvæ and small pupæ, with prominent respiratory horns.

The eggs of the hairy species are laid in decaying vegetal matter, and give rise to small larvæ.

Œcacta Poey 1851.

Œcacta furens Poey is the jejen of Cuba, where it is said to be very irritating.

Tersesthes.

Tersesthes torrens Townsend is another blood-sucker found in Cuba and Mexico. It principally attacks horses.

Mycterotypus Noè.

This genus is found in Italy.

Ceratolophus Kieffer.

This is cosmopolitan.

Hæmatomyidium Goeldi.

Hæmatomyidium paræense Goeldi 1905 is found in South America, and its larvæ are believed to live in the sea.

FAMILY PSYCHODIDÆ.

Orthorrhapha nematocera without ocelli, and with body densely covered with coarse hairs. Thorax without transverse suture. Antennæ long, sixteen-jointed. Wings very broad and hairy. No discoidal cell. Legs long, tibiæ without spurs.

The principal blood-sucking genus is *Phlebotomus* Rondani 1840, but Eaton suspects *Sycorax silacea* Hal. of England and Algeria as being likely to suck the blood of men.

In Ceylon, *Phlebotomus* is very irritating, and we have several times had inquiries *re* this pest. The life-history is not well known, but the eggs are probably laid in water. The larvæ possess a head with ocelli and also have a siphon. They live in liquid filth. Pupæ are free, with stigmata in the form of horns.

Phlebotomus papatasii Scop. 1786, Northern Italy, Austria, and Egypt. Recently *P papatasii* has acquired considerable importance, for it has been proved to be the carrier of 'papataci fever' endemic in Bosnia and Herzegovina and Dalmatia; *P. minutis* Rondani Europe; *P. duboscqui* Neveu-Lemaire, 1906, in Timbuktu. An Indian species has been suggested to be one of the possible carriers of surra.

FAMILY SIMULIDÆ.

Synonyms.—*Tipulariæ latipennis* Meigen, *Simulides* Zelt, *Simulites* Newman, *Simulinæ* Rondani.

Orthorrhapha nematocera without ocelli; without transverse suture on the thorax; with short legs, in which the posterior tibiæ and the first joint of the hind tarsi are dilated; with short straight cylindrical, eleven-jointed antennæ without setæ. Eyes of the male are large, and meet in the middle line, while those of the female are smaller and separate. Size, 1·5 to 4 millimetres in length.

The *Simulidæ* are the sand-flies, also called 'brûlots' or 'potu' flies, and have a wide distribution, being particularly found in the tropics, but are also well known in Europe. Though small in size, they are great blood-suckers, attacking man and beast, and also other insects, but only the females suck blood.

Though there is only one genus, *Simulium* Latreille 1802, there are very many species—*i.e.*, about seventy—of which *Simulium reptans* Latreille and *S. hirtipes* Fries are known in Scotland. *S. columbaczense* Schönberg, locally known as the 'banat,' is the cause of much destruction of cattle in South Hungary. *S. indicum* Becher is the 'dam din' of Assam, which is a cause of irritation to tea-coolies. *S. damnosum* Theobald in Uganda, where it is called 'mbwa,' and in the Sudan, where it is called 'kunteb'; and *S. griseicollis* Becher, of Dongola, locally called 'nimetta,' are very virulent. Austen says that the 'potu' flies were accused of having caused the death of coolies while constructing an Indian road. The effects of the bite of these small insects is most irritating, and the appearance of a person after a severe attack is most peculiar, the face and hands—*i.e.*, the exposed parts—being covered with papules.

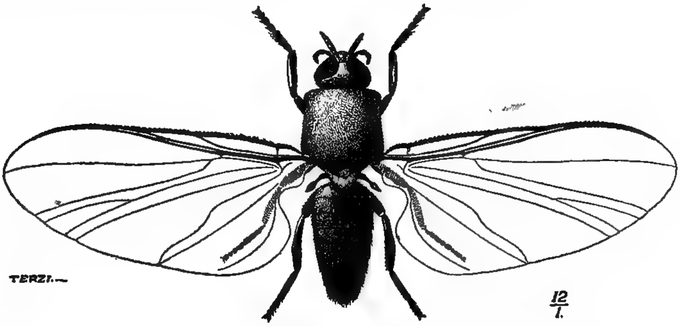

FIG. 237.—SIMULIUM REPTANS (FEMALE).

The eggs are deposited in running water, being attached to stones or plants. The larva is broad posteriorly, where it possesses a sucker, capable of attaching it to any convenient object. Anteriorly it has two fan-like organs. It moves about in the water after the manner of a leech, and feeds on water plants. The larval stage lasts about a month, when a cocoon is spun, inside which the pupa is formed. The pupa breathes by means of branched filaments, and at the end of a week becomes the imago, which is carried to the surface of the water in an air-bubble.

Pathogenesis.—Although sand-flies are very irritating, and cause the death of cattle, it is not known whether they are the carriers of any definite disease of cattle or man.

Marchoux and Borret have suggested that sand-flies may play a rôle in the transmission of leprosy.

FAMILY BLEPHAROCERIDÆ Loew 1860.

Orthorrhapha nematocera, without discal cell and with a secondary set of crease-like lines on the wings.

In this family the genus *Curupira* Osten-Sacken is said to contain species which suck blood. The larvæ live in rapid streams. *C. torrentium* (Müller) is found in Brazil.

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CHAPTER XX

BIOLOGICAL CAUSES OF DISEASE (*continued*) —FLIES

Flies — Orthorrhapha — Brachycera — Tabinidæ — Asilidæ — Leptidæ — Empidæ—Cyclorrhapha—C. Aschiza—C. schizophora—Œstridæ—Dermatobia — Sarcophagidæ — Muscidæ — Stomoxys — Glossina — Musca—Callophorinæ — Chrysomyia — Lucilia — Cordylobia — Auchmeromyia —Oscinidæ—Anthomyidæ—Pupipara—References.

FLIES.

THIS chapter deals with all those insects which come under the term 'flies.' In medicine they are of importance because of either their blood-sucking habits, through which they are able to disseminate animal parasites, or of their capability of carrying germs on the hairs of their legs and body, or in their alimentary canal. These germs are liable to be deposited on food, either by being brushed off the hairs or by being deposited with the fæcal matter of the flies. Further, their larvæ are apt to enter the skin or the alimentary canal, and cause irritation and disease in this way.

Continuing the classification of the Diptera already given, the first group included in this chapter is the section Brachycera.

SUBORDER I. ORTHORRHAPHA.

SECTION BRACHYCERA.

The Orthorrhapha brachycera may be divided into two tribes :

TRIBE 1. BRACHYCERA HOMŒODACTYLA.—Imago with three similarly formed pulvilli. Larvæ with a terminal posterior stigma. Families : Tabanidæ, Leptididæ, Stratiomyidæ.

TRIBE 2. BRACHYCERA HETERODACTYLA.—Imago with two or three pulvilli ; in the latter case the middle one is different from the two lateral. The pulvilli may, however, be entirely wanting. Posterior stigma of the larva is not terminal. Families : Bombyliidæ, Therevidæ, Midasidæ, Asilidæ, Empididæ, Dolichopodidæ.

TABANIDÆ.

Orthorrhapha brachycera with broad, flattened bodies and large head. The eyes meet in the males, but are separate in the females. Antennæ with third joint marked by five to six annuli, but is generally entire, and has no terminal bristle. Proboscis strong and prominent. Thorax narrower than the head. Wings with three basal cells very prolonged. Third longitudinal vein bifurcate, and two intercalary veins. Legs moderately stout. Empodia large.

The Tabanidæ are blood-sucking flies, of which some 1,500 to 2,000 species are known. The blood-sucking is confined to the females, while the males live on the juices of plants. They are variously known as horse-flies, breeze-flies, gad-flies, serut-flies (Nile), and mangrove-flies (West Africa), and are distributed widely over the world. They are in the habit of coming to water for drinking purposes, and this has enabled them to be killed in large numbers by sprinkling the water with kerosene, which probably prevents them escaping from the surface of the water, and partially kills them by its poisonous effects.

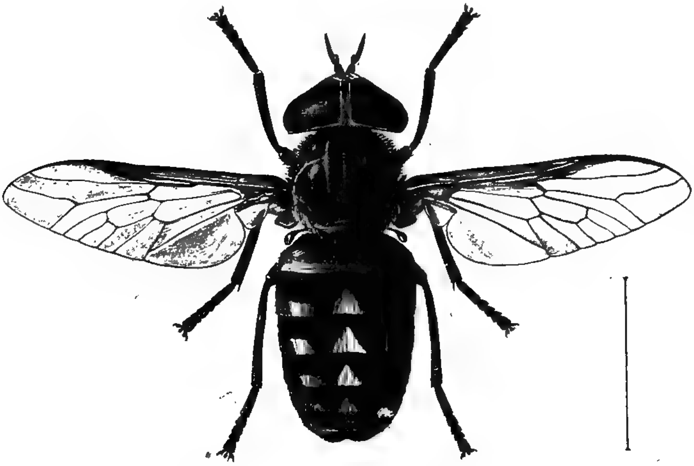

FIG. 238.—TABANUS BOVINUS (FEMALE).

Morphology.—As a rule the head is as wide or wider than the thorax, convex anteriorly, and concave posteriorly, with very large, brilliantly coloured eyes, with golden green or purple markings.

The antennæ are very distinct, but the proboscis varies, being very short in some genera and enormously long in others. In the genera in which it is short it hangs vertically downwards from the head. It consists of a labrum, two maxillæ with palps, two mandibles, a hypopharynx, and a thick labium with well-marked labial palps (labellæ). The wings have a large discoidal cell and very elongate basal cells. When at rest the wings diverge at the tips. They may be mottled. The legs are large and strong. The body is brown or black in colour, but there may be markings on the abdomen.

Life-History.—The eggs, which are spindle-shaped, and either brown or black, are laid in raft- or flask-shaped masses attached to water-plants. The larvæ live either in water or damp earth, and feed upon other small animal organisms. They are spindle-shaped and segmented, with knobs or protuberances on the rings, either all round or only ventrally.

The pupa, which is free, is found in water or damp rubbish.

Pathogenesis.—It is possible that they may disseminate trypanosomes. The diseases mbori in dromedaries in Timbuktu, and souma in Segon, are believed to be spread by *Tabanus ditæniatus*, while the dromedary disease of Algeria is spread by *T. nemoralis* Meigen and *T. nigritus* Fabricius. They are among the suspects for the transmission of *Filaria loa*. *T. glaucopis* Meigen is infected with *Herpetomonas subulata*.

Prophylaxis.—Kerosene spread on water appears to be the best method of dealing with these pests.

Classification.—The family is divided into two subfamilies: Tabaninæ and Pangoninæ.

TABANINÆ.

Tabanidæ without spurs on the hind tibiæ.

The important genera of the Tabaninæ may be recognized by the following table:

I. Thorax and abdomen with iridescent tomentum—*Lepidoselaga*.

II. Thorax and abdomen without iridescent tomentum.

1. Eyes bare.
    - (*a*) Third joint of the antenna without basal tooth—*Hæmatopota*.
    - (*b*) Third joint of the antenna with well-developed basal tooth—*Tabanus*.
2. Eyes pubescent.
    - (*a*) With ocelligerous tubercle—*Thierioplectes*.
    - (*b*) Without ocelligerous tubercle—*Atylotus*.

Lepidoselaga Macquart 1838.

Synonym.—*Hadrus*.

Lepidoselaga lepidota Wiedemann 1828 the motúca fly of Brazil, is a well-known biter.

Hæmatopota Meigen 1803.

Synonym.—*Chrysozona* Meigen 1800.

This genus includes some sixty-two species. *Hæmatopota pluvialis* Linnæus is a common European bloodsucker. *H. italica* Meigen is another European species. There are about twenty African species known. The genus *Hippocentrum* Austen 1908, with species *H. versicolor* Austen 1908, found in Uganda, and nearly allied to *Hæmatopota* is said to be a biter.

H. obscura Loew 1875, known in South Africa; *H. guineensis* Bigot 1891, in the Cameroons; *H. strigipennis* Karsch 1889, in Gabun; *H. pulchrithorax* Austen 1906, found in British Central Africa, Uganda, and the Sudan, may be mentioned as examples.

Tabanus Linnæus 1761.

There are over 900 species of *Tabanus* known, of which *Tabanus bovinus* Linnæus 1761 is found in Europe, Asia, and South Africa. In the Sudan these flies are called serut-flies, of which *T. ditæniatus* Macquart, *T. gratus* Loew, *T. socius* Walker, *T. virgatus* Austen, *T. fasciatus* Fabricius, *T. africanus* Gray, may be noted. In West Africa they form one variety of the mangrove-fly. Recently Patton has described the life cycle of a Crithidia (*C. tabani* Patton 1909), which is a true parasite of *T. hilarius* and another species.

Therioplectes Zeller 1842.

A number of species of this genus are known in Europe. *Therioplectes micans* Meigen, *T. borealis* Meigen, *T. montanus* Meigen, and *T. tropicus*, may be mentioned.

Atylotus Osten Sacken 1876.

Atylotus fulvus Meigen and *A. rusticus* Fabricius are met with in Europe.

PANGONINÆ.

Tabanidæ with hind tibia armed at the tip with spurs.

I. Proboscis short.
  1. Antennæ longer than the head—*Chrysops.*
  2. Antenna shorter than the head—*Silvius.*

II. Proboscis long.
  1. Proboscis little longer than the head—*Cadicera.*
  2. Proboscis usually much longer than the head, often longer than the body—*Pangonia.*

Chrysops Meigen 1803.

This genus is world-wide in its distribution, and contains about 160 species, of which fifteen to sixteen are African, where they form a variety of the mangrove-fly—*e.g.*, *Chrysops dimidiata* Wulp 1885 is found in the Cameroons, *C. distinctipennis* Austen in Uganda, and *C. dispar* Fabricius in India and Ceylon.

Silvius Meigen 1820.

This genus is also cosmopolitan—*e.g.*, *Silvius denticornis* Wiedemann is known in South Africa.

Cadicera Macquart 1855.

Of this genus, *Cadicera melanopyga* Wiedemann and *C. chrysostigma* Wiedemann are reported in South Africa.

Pangonia Latreille 1802.

In this genus are gathered about 255 species, spread all over the world, and common in Africa and Asia—*e.g.*, *Pangonia rostrata* Latreille 1764, and *P. varicolor* Wiedemann 1828.*

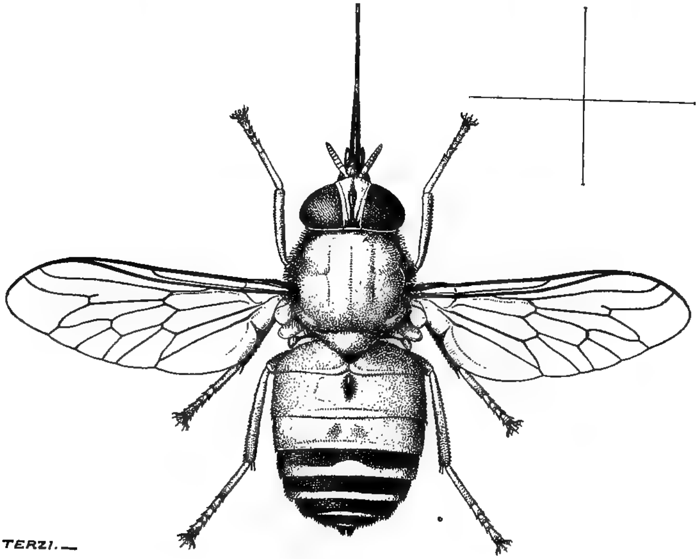

FIG. 239.—PANGONIA RÜPPELLII JAENN (FEMALE). × 3.

ASILIDÆ.

Orthorrhapha brachycera with long narrow body, short broad head, prominent eyes, third joint of the antennæ simple. Thorax narrow in front. Wings with elongate basal cells, third longitudinal vein bifurcate, two intercalary veins present. Empodium with a horny bristle.

It is not known whether the Asilidæ are really blood-sucking flies or not. It is suspected that they bite in the tropics, but there is no definite information.

LEPTIDÆ.

Orthorrhapha brachycera with brownish, medium-sized or long narrow bodies and small heads. The third antennal joint is short, and carries either a terminal brush or bristle. The proboscis resembles that of the Tabanidæ, as does the wing venation.

Three genera are accused of blood-sucking: *Leptis*, *Symphoromyia*, and *Trichopalpus*.

With regard to *Leptis*, the species *L. scolopacea* Linnæus and *L. strigosa* Meigen are said to bite persons in France, but this is rare. *Symphoromyia*

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* *Rhinomyza* Wiedemann 1820, an undescribed species of the genus from Northern Nigeria, is mentioned by Austen on Pirie's authority to be a bloodsucker.

(species uncertain), characterized by a single spur on the hind tibia and a kidney-shaped third antennal joint, is found in California. *Trichopalpus obscurus* Phil. is known in Chili.

The life-history of the blood-sucking species is not known, but the other larvæ of the Leptidæ live upon decaying vegetable matter.

EMPIDÆ.

Orthorrhapha brachycera with medium or small bodies and small heads. Antennæ with the first two joints very small and hardly distinct, the third joint annulated, often with terminal bristle. Wings with three large complete basal cells, of which the third is shorter than the second. The posterior basal transverse vein is parallel to the border of the wing. Empodium membranaceous.

It is doubtful whether these insects attack man. As a rule they live on the juices of other insects and plants.

The orders Therevididæ, Midasidæ, and Dolichopodidæ, while containing species predatory on other insects, do not appear to attack man.

SUBORDER II. CYCLORRHAPHA.

Section 1. Aschiza.—This group includes the family Syrphidæ, of which no species is known to bite man.

Section 2. Schizophora.—This group includes the true flies, which are classed into: Tribe 1. Muscidæ acalyptratæ, without squamæ covering the halteres.* Tribe 2. Muscidæ calyptratæ, with squamæ covering the halteres, of which the former is not of importance to us, while the latter include the following families:

1. Œstridæ.
2. Sarcophagidæ.
3. Muscidæ.
4. Anthomyidæ.

DIAGNOSTIC TABLE.

A. First posterior cell of the wings not widely open.
  I. Antennæ small, more or less hidden in round pits arista single or plumose; body very hairy—Œstridæ.
  II. Antennæ well marked, not hidden; arista more or less plumose; body not very hairy.
    (*a*) Arista plumose for only half its length, bare in the terminal half, which is hair-like—Sarcophagidæ.
    (*b*) Arista plumose or pectinate along its whole length—Muscidæ.

B. First posterior cell widely open—Anthomyidæ.

ŒSTRIDÆ.

Muscidæ calyptratæ with very hairy bodies, which cause them to resemble bees. Antennæ inserted into round pits, with a terminal bristle on the third joint. Mouth parts rudimentary.

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* The family *Sepsidæ* contains the genus *Piophila*, the larvæ of which are called 'cheese-mites.' Alessandrini has shown that the larvæ of *Piophila casei* may cause intestinal myiasis.

The Œstridæ are commonly known as the bot or warble flies, and are of interest because the larvæ become parasitic, either under the skin, in the nasal or pharyngeal cavities, or in the alimentary canal.

A good example of the first kind of infection is *Hypoderma bovis* de Geer, which infests cattle. The eggs are laid on the skin of the animal, and are probably transferred to the mouth by licking, whence they pass viâ the œsophagus to the skin, in which they form tumours. It is found in Europe and America, and Peiper has gathered together histories of several cases in which *Hypoderma bovis* and *H. diana* Brauer have occurred in man, but this is very rare. The species which is commonly found in man is *Dermatobia cyaniventris*, which is described below.

The second type of parasitism is exemplified by *Cephalomyia ovis* Linnæus 1761, which has been found several times in the nasal cavities of man, though usually found in sheep. The egg is laid in the nasal cavity, in which the larvæ live until they become pupæ.

An example of the third type is found in *Gastrophilus equi Fabricius.* The eggs are laid on the skin, often about the knees, and transferred to the mouth, and so to the stomach, by licking. In this organ they live on the secretions and contents; but though they do not bite the mucosa, they cause irritation. In due course they pass out of the alimentary canal with the fæces, and then proceed to pupation.

The genera—*Gastrophilus*, *Hypoderma*, and *Dermatobia*—may be recognized as follows:

I. Wing without posterior transverse vein; the media runs towards the posterior border. First posterior cell is partly open. Arista naked—*Gastrophilus* Leach 1817.

II. Wing with posterior transverse vein. The media at its end is bent towards the radius, and the first posterior cell is either open, partially open, or closed.

  A. Proboscis straight, capable of being extended, or entirely rudimentary. Antennal groove with small angular dividing wall. Palpi absent—*Hypoderma* Latreille 1825.

  B. Proboscis bent and capable of being drawn into a deep cavity on the under surface of the head, and generally hidden therein. Arista with hairs on the upper side. Third antennal joint much longer than the first two—*Dermatobia* Brauer 1860.

Dermatobia Brauer 1860.

Dermatobia cyaniventris Macquart 1843.

Synonyms.—*Cuterebra noxialis* Goudot 1845, *Dermatobia noxialis* Brauer 1860.

There appears to have been great doubt as to whether *D. noxialis* is the same as or different from *D. cyaniventris.* At present, on the strength of R. Blanchard's observations, it is usual to look upon them as the same. The larva of this species is found in the skin of man in tropical America at times, and is known by various local names : 'Ver moyoquil' in Mexico ; 'ver macaque' in Cayenne ; 'cormollote' in British Guiana ; 'torcel' in Venezuela ; 'nuche' in Colombia ; 'ura' and 'berne' in Brazil ; 'anal coshol' in British Guiana ; 'nuche' or 'gusano' in New Granada.

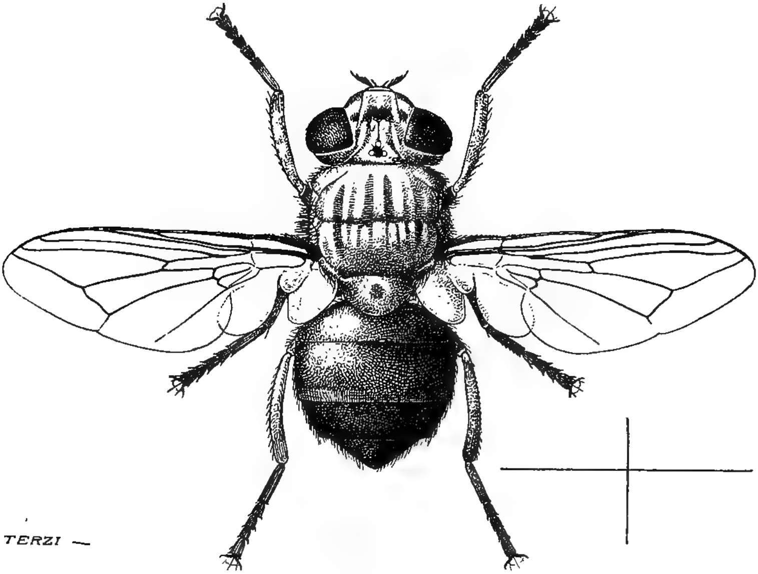

FIG. 240.—DERMATOBIA CYANIVENTRIS (FEMALE). × 3.

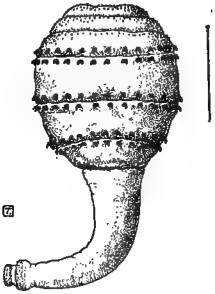

FIG. 241. — DERMATOBIA CYANIVENTRIS (YOUNG LARVA). × 3.

(After Blanchard.)

The fly, which has a yellowish head and dark blue abdomen, is supposed to lay its eggs on the skin of domestic and wild animals and man. The larvæ from these eggs are supposed to enter the skin. The usual areas affected are the head or trunk.

The larva presents two quite different appearances. In the first they are club-shaped, white in colour, with a thick anterior and a thin posterior end. The anterior portion is beset with hooklets, and has two strong oral hooks. The posterior end carries the stigmata.

If left to themselves, the larvæ will remain in the skin for some time, after which an abscess forms, and they are thrown out, drop on to the ground, and become pupæ, and finally imagos.

We have seen larvæ resembling these in the skins of Europeans in Africa, and similar observations have been made by Plehn, Strahan, Kolb, Nagal, Arnold, and Smith and others, but whether these are *D. cyaniventris* or some other species has not been determined.

Pathogenesis.—They cause pain and itching at the infected spot, with swelling and œdema of the surrounding region, giving rise to a boil-like swelling, rather hard, of a deep red colour, with a central opening.

Treatment.—On inspecting the region, a small opening will be seen, and the larva may be noted, showing its stigmata at times, and at other times disappearing and reappearing like a jack-in-the-box. There is no difficulty in seizing this parasite with a pair of forceps and forcibly removing it, and then treating the wound antiseptically. The Brazilians try to asphyxiate the larva by tobacco-smoke, or apply some animal fat to the opening in the little tumour. The fat is said to act by preventing the larva from breathing and compelling it to leave the tumour. Some authors advise the application of calomel to the opening. no.

Dermatobia (?) **keniæ** Kolb.

Kolb described a reddish-brown fly in East Africa under this term.

The fly behaved like *D. cyaniventris* in laying its eggs on the skin of people when bathing. The larvæ entered the skin, forming nodules. The natives called the fly 'ngumba.' It is, however, possible that this is not a true *Dermatobia*, which is a New World genus.

SARCOPHAGIDÆ.

Muscidæ calyptratæ with large bodies, and antennal bristles feathery at the base, but hair-like and very fine at the tip. Legs stout. First posterior cell closed or only slightly open.

The Sarcophagidæ are the blow-flies, of which *S. canaria* is common.

Genera.—*Sarcophaga, Sarcophila, Cynomyia.*

Sarcophaga Meigen 1826.

It is by no means uncommon in the tropics to find ulcers, and especially syphilitic erosions of the nose, infected with larvæ of flies, which may belong to *S. canaria* Linnæus 1758 or to *S. magnifica* Schiner 1862, synonym—*S. wohlfahrti* Portschinsky 1875, which is found in Europe, especially in Russia.

The larvæ of both have also been found in several cavities of the human body, and those of the former in the alimentary canal. Peiper gives the following as causes of intestinal myiasis: *S. affinis*, *S. canaria* Linnæus 1761, *S. hæmorrhoidalis* Fallen 1810, *S. hæmatodes.*

Sarcophila Rondani 1856.

The larvæ of species of this genus—*e.g.*, *S. meigeni* Schiner, *S. latifrons* Fall., and *S. ruralis* Fall.—may also be found in ulcers, etc., in Germany, Austria-Hungary, and France.

Cynomyia R. Desvoidy 1830.

Cynomyia mortuorum Linnæus 1761 is believed to infect ulcers with its larvæ.

MUSCIDÆ.

Muscidæ calyptratæ with stout bodies and short thoraces. Arista either entirely plumose or pectinated. The first posterior cell is either only slightly opened, or else closed at the border of the wing.

The Muscidæ include a number of important genera, which may be recognized by the following table :

A. Proboscis long ; adapted for biting.
  - (*a*) Palpi thin, shorter than the proboscis.
    - (1) First posterior cell open—*Stomoxys*.
    - (2) First posterior cell closed—*Beccarimyia*.
  - (*b*) Palpi thickened, as long as, or nearly as long as, the proboscis.
    - (1) Palpi club-like, with only the tip thickened. Vertical diameter of the head not greater than the antero-posterior. Eyes oval—*Hæmatobia*.
    - (2) Palpi thickened from base to apex. Vertical diameter of the head greater than the antero-posterior. Eyes kidney-shaped—*Lyperosia*.
  - (*c*) Palpi strongly built everywhere, not thickened.
    - (1) Proboscis thick, less than twice the head length. Arista with few unbranched hairs. Median (fourth longitudinal vein) of the wings without sharp bends—*Glossinella*.
    - (2) Proboscis thin, more than twice the head length, swollen at the base. Arista with many branched hairs. Media (fourth longitudinal) with two sharp bends—*Glossina*.

B. Proboscis short, not adapted for biting.
  - (*a*) Mid-tibia without bristle on inner side—*Musca*.
  - (*b*) Mid-tibia with bristles on inner side.
    - (1) Thorax blackish—*Calliphora*.
    - (2) Thorax black, with whitish stripes—*Chrysomyia*.
    - (3) Thorax unicoloured—*Lucilia*.

STOMOXYDINÆ.

Stomoxys Geoffry 1764.

The genus *Stomoxys* is cosmopolitan in its distribution. The type species is *S. calcitrans.*

Stomoxys calcitrans Linnæus 1761.

S. calcitrans is the common stable-fly, found in houses, stables, and in the open near cattle. It bites all classes of mammals, and in so doing is suspected of spreading trypanosomes, especially *T. evansi.* Manders considered *S. nigra* Macquart 1850 to be the cause of the spread of surra in Mauritius.

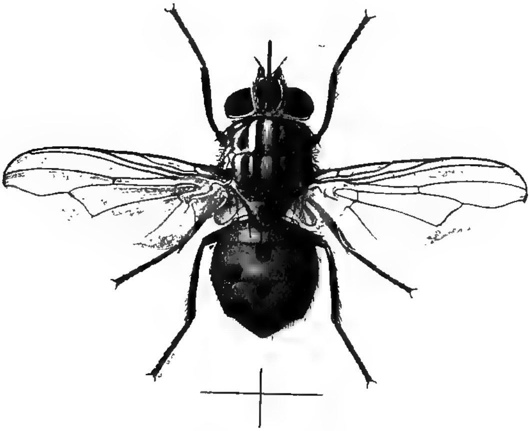

Fig. 242.—Stomoxys calcitrans (Female).

It is rather like the common house-fly, but is easily recognized by the head being raised in the resting position, by the projecting proboscis, and by the closed wings, touching one another at their bases, and diverging behind.

Morphology.—The mouth parts consist of a proboscis, composed of rostrum, haustellum, and labellæ, which are bent posteriorly, forming an elbow-shaped joint. The posterior portion can be retracted or projected forwards, and carries the chitinous fulcrum of the pharyngeal wall, the maxillæ, and their palps. It is cone-shaped, and is called the rostrum.

The structure of the haustellum or proboscis proper is very complex. It consists essentially of a labrum, hypopharynx, and labium. The labrum is a sharp-pointed stylet, which near its apex bears a ventral ridge with four sensory hairs. Posteriorly it is attached to the head, where it forms a chitinous projection. It is horseshoe-shaped on transverse section, the ventral opening being closed by the hypopharynx, while laterally its walls, which expand and enclose a cavity containing muscles, articulate with the labium, thus keeping the hypopharynx in its place. The hypopharynx, which contains the salivary tube, starts from the labium and runs forwards, expanding laterally and closing in the labral, pharyngeal, or blood tube mentioned above. Its lateral expansions contain a cavity. At its tip it appears to be membranous, which Stephens and Newstead think by its flaccid condition prevents ingress of fluid during blood-sucking, while freely permitting the egress of saliva. The labium is stout and thick, with a swollen basal portion, gradually tapering towards the proximal and distal extremities, but less so basally. Posteriorly it encloses the labrum and hypopharynx, which it carries on a sclerite, which farther forwards forms the boundary of the labial gutter, and is joined dorsally by another dorsal hooked sclerite. These sclerites stop at the base of the labellæ. Ventral to the dorsal sclerites are two ventral sclerites, which anteriorly articulate with a transverse forked sclerite whose arms run forwards. To these arms the tendons of longitudinal muscles are attached, which are capable of rotating them, causing the eversion of the labellæ. Farther forward the two labellæ are strengthened internally by dorsal and ventral sclerites, while a pear-shaped axial apophysis projects forwards freely from the labium.

The ventral plate is obliquely placed, and carries—(1) five teeth ; (2) nine sets of petiolated blades ; (3) six sets of rod-like hairs ; (4) five sets of operculate hairs ; (5) six sets of bifurcated hairs ; (6) an anterior dorsal fringe of hairs ; (7) a posterior ventral set of hairs ; (8) ventral phanges or lips with ventral hairs ; (9) dorsal external set of hairs ; and (10) latero-external set of hairs.

Internal Anatomy.—The pharyngeal tube leads into the pharynx, whose wall is formed by the chitinous fulcrum. The œsophagus, at first flattened, afterwards cylindrical, passes into the thorax and opens into the ventral surface of the proventriculus. At this point it is joined by the duct from the crop or sucking-stomach, which is a large hollow blood reservoir lying in the abdomen. The chilific ventricle has three coils. The usual Malpighian tubules, small and large intestine, and rectum are present. The salivary glands resemble those of *Musca* and *Glossina*.

Method of Biting.—*Stomoxys* carefully inspects the skin, and having selected a spot, everts the labellæ, and by a rotatory motion cuts a hole through the epidermis by means of its teeth, and then, inserting the proboscis into the wound, sucks the blood.

Life-History.—The life-history has recently been studied by Newstead, who finds that the incubation period of the egg is two to three days, the life of the larva fourteen to twenty-one days, the pupal stage nine to thirteen days, making the total life-cycle twenty-five to thirty-seven days, but this may be considerably prolonged by the incubation and larval stages being lengthened in the absence of moisture, or the presence of a low temperature.

The eggs are 1 millimetre in length, white, turning later to a cream colour ; coriaceous and reticulated ; curved on one side and straight on the other, where there is a broad deep groove, wider anteriorly, where the larva escapes. The number of eggs varies from forty-eight to seventy-one, and they are laid in warm dung and fermenting grass.

The larva is 11 millimetres long, and tapering, yellowish in colour, with blackish mouth parts. The segmentation is not well marked. The head has two large diverging processes, which carry the four-jointed antennæ. The mouth is armed with a hook-like mandible, which carries a ventral tooth, and is attached by means of a hypostomal sclerite to two large cephalo-pharyngeal sclerites, in front of the upper arms of which is a small perforated sclerite. The posterior stigmata are two in number. The mouth-hook is used for locomotion.

Pupation is brought about in two hours by the larva shortening itself and becoming barrel-shaped, the colour turning to red. The pupa measures 5 to 5·5 millimetres in length, and possesses eleven visible segments. In a few days the pupal skin is split along lateral and median lines anteriorly, and at the fourth segment transversely, and the imago escapes.

There are a number of known species of *Stomoxys*, of some of which the following table, modified from Grünberg, gives the diagnosis :

- A. Legs entirely yellow. Wings yellowish—*S. tæniatus* Bigot 1887.
- B. Legs either entirely black or largely black or blackish-brown. Wings clear or darkish coloured.
  - I. Venter brilliantly white—*S. sitiens* Rondani 1873.
  - II. Venter pale dusky brown, with characteristic omega mark on the thorax—*S. omega* Newstead 1907.
  - III. Venter grey or yellow.
    - 1. Thorax without clear black stripes. Hinder part black without any markings—*S. inornata* Grünberg 1906.
    - 2. Thorax with clear black stripes. Abdomen with regular dark marks or spots.
      - (*a*) Knee, tibia, and tarsus—at all events, on the two anterior pairs of legs—entirely brown.
        - (1) Tibia and tarsus on the anterior and middle legs light brown, on the hind legs dark brown. Thorax with two small brown longitudinal median lines—*S. bilineata* Grünberg 1906.
        - (2) Tibia and tarsus brown on all three legs. Thorax with broad black longitudinal stripes.
          - Wings blackish, head and thorax brown-yellow—*S. brunnipes* Grünberg 1906.
          - Wings glassy, head and thorax grey—*S. sellata* Grünberg 1906.
      - (*b*) Legs black, with light brown knees or decidedly dark brown spots.
        - (1) Wing brushes yellowish-brown, with black tips. Abdomen with dark middle longitudinal line. Second and third segments with dark anterior and posterior borders—*S. glauca* Grünberg 1906.
        - (2) Wing brushes black. Abdomen grey. Both middle segments with regularly arranged dark spots without dark median longitudinal line.
          - Second and third abdominal segments with one middle basal, one side apical dark spot, and dark anterior border, with which the basal spot unites—*S. korogwensis* Grünberg 1906.
          - Second and third abdominal segments with the same dark spots, but without anterior border-lines—*S. calcitrans* Linnæus 1761.

Other species are *S. nigra* Macq. 1850, found in Mauritius ; *S. limbata* Austen 1909, in India and Ceylon ; *S. pusilla* Austen 1909, in India ; and *S. pulla* Austen 1909, in India.

Beccarimyia Rondani 1873.

This genus is represented by a single species, which was alleged to bite, found near Massowah; but Grünberg says that *Beccarimyia* is merely a synonym for *Rhinia* Robineau-Desvoidy. Bezzi says that it is a non-blood-sucking genus.

Hæmatobia Robineau-Desvoidy 1830.

Synonym.—*Siphona* Meigen 1803.

There are three known species of this genus, two in Europe and one in Java. *H. stimulans* Meigen 1824 is the best known of these. None are reported so far from Africa, but *H. sanguisugens* Austen 1909 is found in Kasauli, India.

Lyperosia Rondani 1862.

The typical species is *L. irritans* Linnæus 1761, found in North and Middle Europe, besides which *L. minuta* Bezzi 1892, in Somaliland, is described, and Austen says that undescribed and probably distinct species are reported from West Africa, Sokotra, and Ceylon. Recently he has described *L. punctigera* Austen 1909 from Uganda.

Stygeromyia Austen 1907.

In general appearance like *Stomoxys*, proboscis and palpi like *Siphona*, but arista feathered only on upper side. Wing with first posterior cell narrowly open at the top.

In this genus *Stygeromyia sanguinaria* Austen 1909 is stated by Yale Massey to be a blood-sucker in the Congo Free State, while *S. maculosa* Austen 1907, found in Little Aden, is inferred to be also a blood-sucker.

Bdellolarynx Austen 1909.

Flies like *Siphona*, but without sexual colour, dimorphism, arista with long hairs above and below, with six fairly long hairs.

B. sanguinolentus Austen 1909 is a blood-sucker found in India and Ceylon.

Glossinella Grünberg 1906.

There is only one known species, *Glossinella schillingsi* Grünberg 1906, found in German East Africa. *Glossinella*, however, may only be a synonym of *Lyperosia*, and therefore not a separate genus.

Other Species.—Austen says that two species for which a new genus will have to be created have been recently received from West Africa and India; probably many more will be found later.

Glossina Wiedemann 1830.

Synonym.—*Nemorhina* Robineau-Desvoidy 1830.

Narrow bodies, elongate, greyish-brown or yellowish-brown, dull-coloured flies, with the wings closed flat over one another, and projecting considerably beyond the abdomen when at rest, with an anterior projecting proboscis, beyond which the palpi slightly extend, and to which they are closely applied. Base of proboscis bulbous.

This is the genus of the tsetse-flies, a name probably derived from the noise which they make when flying, and now used in a generic sense. They were first named by Wiedemann from *G. longipalpis*, brought from Sierra Leone by Adam Afzelius, and in the same year Robineau-Desvoidy named another species from the Congo *Nemorhina palpalis*. Their bites have been long known to be dangerous to animals, but it was not till Bruce showed that they were the spreaders of *Trypanosoma brucei* and the cause of the disease nagana in horses, etc., that they received much attention.

The interest in them became vastly greater when in 1903 Bruce and Nabarro showed that they were the spreaders of *T. gambiense*, and especially when Kleine showed that the transmission was not mechanical.

The genus is confined to Tropical Africa and Arabia.

Morphology.—The points in the morphology to which attention should be paid are as follows:

The eyes are large and bare, and between them the vertex is depressed, and at its back carries ocelli. In front a deep facial pit is separated by a transverse impression from the gena. The proboscis projects horizontally forwards, while its bulbous posterior portion is enclosed in a fold of skin. Palpi are rod-like, and clothed with short black hairs, and enclose the proboscis. The antennæ are three-jointed, the first two being small and the third large, with its anterior external angle prominent and directed forwards and outwards. At its base is attached a two-jointed arista, of which the first segment is small, and the second long and tapering, bearing some twenty-two fine, curving, branched hairs on its upper surface only. Bristles are frontal, vertical, ocellar, and post-medial.

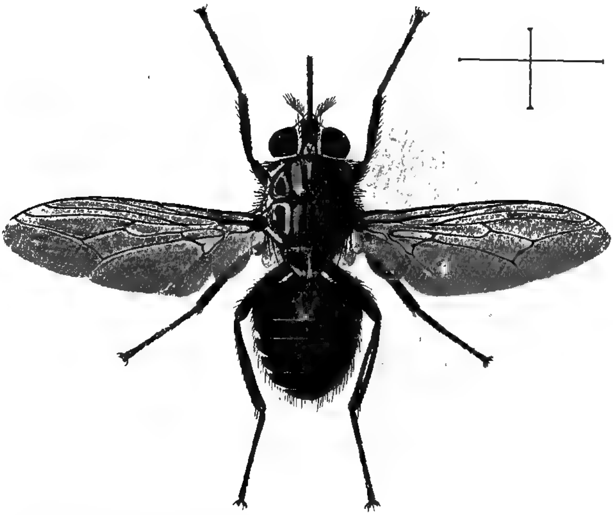

FIG. 243.—GLOSSINA PALPALIS (FEMALE).

With regard to the thorax, the most important feature is the wing, which is brownish, with a peculiar venation. The costal vein is well marked, and the subcostal vein (auxiliary) joins it about the

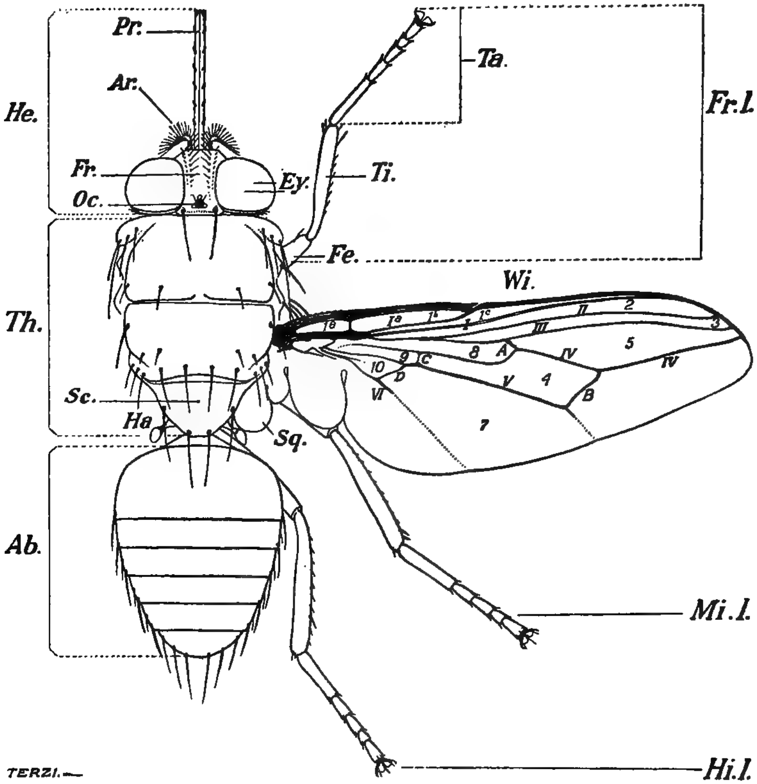

FIG. 244.—DIAGRAM OF A TSETSE-FLY.

(Modified after Austen, from 'Monograph of Tsetse-Flies.')

He., head; *Th.*, Thorax; *Ab.*, abdomen; *Fr. l.*, front leg; *Mi. l.*, middle leg; *Hi. l.*, hind leg; *Pr.*, proboscis; *Ar.*, arista; *Fr.*, frons; *Oc.*, occiput; *Ey.*, eye; *Sc.*, scutellum; *Ha.*, haltere; *Sq.*, squama; *Wi.*, wing; *Fe.*, femur; *Ti.*, tibia; *Ta.*, tarsus.

Venation of Wing.—*Ia*, Subcostal or auxiliary vein; 1*a*, 1*b*, two portions of the costal cell divided by the humeral transverse vein; 1*c*, subcostal cell; *I*, radius 1, or first longitudinal; 2, marginal cell; *II*, radius 2 and 3, or second longitudinal; 3, submarginal cell; *III*, radius 4 and 5, or third longitudinal; 8, first basal cell; 5, first posterior cell; *A*, anterior transverse vein; *IV*, media or fourth longitudinal; 9, posterior basal cell; 4, discoidal cell, external to which is the second posterior cell, without a number; *B*, posterior transverse vein; *C*, anterior basal vein; *V*, cubitus 1 and 2, or fifth longitudinal; *D*, posterior basal transverse vein; 10, posterior basal cell; 7, third posterior cell; *VI*, anal or sixth longitudinal.

junction of the inner with the outer third in the extended position of the wing, thus enclosing the costal cell, which is divided into two portions by the humeral transverse vein. The radius 1 (first longitudinal) curves forwards, joining the costa about the junction of the inner two-thirds with the outer one-third, thus forming a very narrow subcostal cell. The radius 2 and 3 (second longitudinal) also curves forwards, meeting the costal margin before the tip of the wing is reached, as does the radius 4 and 5 (third longitudinal); hence the marginal and submarginal cells are long and narrow. The media (fourth longitudinal) is highly characteristic. It starts separately from the preceding, and running outwards, after meeting with the anterior basal vein, curves forwards to join with the anterior transverse vein, when it bends at right angles, turning backwards and outwards to join with the posterior transverse vein, when it again turns and runs obliquely forwards to join the costal vein just in front of the tip of the wing. Between it and the radius 4 and 5 (third longitudinal) lie internally the first (anterior) basal cell, and externally the first posterior cell, separated by the anterior transverse vein, which is very oblique. The cubitus 1 and 2 (fifth longitudinal) joins the anterior basal vein, marking out the posterior basal cell, and then runs forwards to join the posterior transverse vein, marking out the discoidal cell, which is hatchet-shaped, with the handle running up to the anterior basal transverse vein. After this the vein turns backwards to join the margin of the wing, delineating the large second posterior cell. The anal (sixth longitudinal) is very short, being unchitinized after meeting with the posterior transverse basal vein, with which it marks out the posterior basal cell. The third posterior cell is, however, shown by its unchitinized trace. The posterior part of the wing shows an incrassation corresponding to anal 2 and 3.

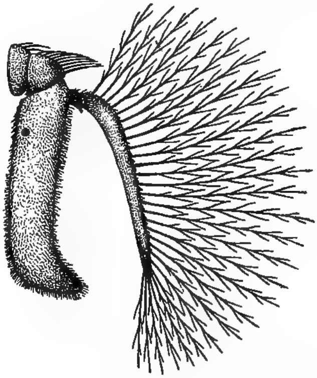

FIG. 245.—ANTENNA OF A GLOSSINA, SHOWING THE ARISTA.

(After Austen, from 'Tsetse-Flies.')

The legs are simple, rather long, with long claws and pulvilli.

The abdomen is flattened, tapering to the apex, and clothed with short black hairs. The male genitalia are characteristic. The ventral plate of the sixth segment carries a patch of dark hairs on each side of the middle line, behind which is the hypopygium, which is oval, tumid, and marked by a vulviform median groove, the anus, running from its anterior margin backwards to beyond the middle.

The proboscis shows the usual rostrum or conical head projection, the haustellum, or proboscis proper, and the labellæ.

The proboscis proper is composed of labrum, hypopharynx, and labium. The labrum arises from the basal bulb of the proboscis in the form of a tube, which is continuous posteriorly with the pharynx, while anteriorly it runs forwards, forming the dorsal wall of the proboscis. In this position it articulates by means of interlocking teeth with the labium, while, opening ventrally, it articulates with the hypopharynx, which closes the potential ventral opening. Farther forwards it separates from the labium, and ends in a point. The tube composed by the hypopharynx and the labrum is the afferent blood or pharyngeal tube. The hypopharynx starts below the pharynx surrounding the salivary efferent duct, and pierces the bulb of the proboscis, appearing on its dorsal aspect. Farther forward it lies in a groove on the labium, articulating laterally with the labrum Finally it ends as a delicate chitinous tube just posterior to the labellæ. Its canal is the salivary tube, or hypopharyngeal canal.

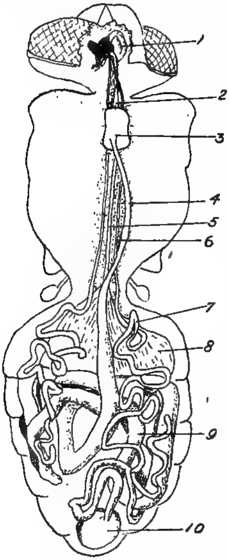

FIG. 246.—ANATOMY OF A TSETSE-FLY.

(After Minchin, from Reports of the Royal Society.)

1, Pharynx; 2, œsophagus; 3, proventriculus; 4, thoracic intestine; 5, duct of sucking stomach; 6, salivary duct; 7, salivary gland; 8, sucking stomach; 9, abdominal intestine; 10, rectum.

The labium (or second maxilla) starts from the ventral area of the head, and is first swollen to form the bulb. Anteriorly it is grooved dorsally to hold the hypopharynx and the labrum, while farther anteriorly it ends in the labellæ. These structures (labellæ) are joined together in the ventral line, except anteriorly, where there is a V-shaped notch, while dorsally they possess teeth which interlock.

In the ventral line the chitinous floor of the labium is prolonged forwards in the form of a fork, in front of which is a membranous area, anteriorly to which the inner wall of each labellum becomes divided into dorsal, median, and ventral segments. Each segment is armed with a series of about ten rasps, composed of some thirty minute bars, in front of which are two pairs of teeth. Between the bases of the anterior pairs of teeth there projects a fan-shaped mass of spine-like scales.

The segments are capable of eversion, when the muscles pull backwards the external walls of the labellæ. In this way the teeth would be brought in contact with the skin, and the wound necessary for blood-sucking made, probably by rotatory movements.

Internal Anatomy.—The internal anatomy has been carefully studied by Minchin, and does not materially differ from that of *Stomoxys*.

The pharyngeal tube opens into the pharynx, which is situated mainly in the rostrum. Its walls are strongly chitinized, forming the fulcrum. The œsophagus runs upwards and then backwards to open into the proventriculus, and to be continuous viâ a long ventral duct, with the crop, which lies in the first two segments of the abdomen. The chylific ventricle is narrow at first in the thorax, but becomes wider in the abdomen, where it coils several times. There are the usual ileum, colon, rectum, and Malpighian tubules.

The salivary glands are two long coiled tubes lying first in the abdomen, and then passing into the thorax, and probably opening finally on the hypopharynx, though this has not yet been worked out.

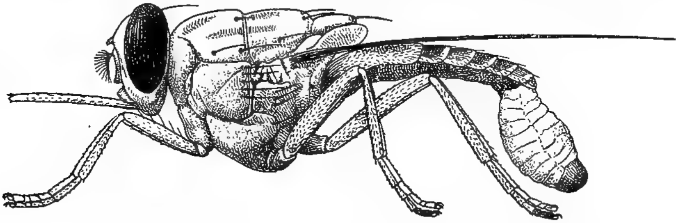

FIG. 247.—A GLOSSINA IN THE ACT OF GIVING BIRTH TO A LARVA. (Modified after Newstead.)

Life-History.—*Glossinæ* live in jungles or bush, along the banks of streams or lakes. They appear to live principally upon the blood derived from big game, but Koch believes that *G. palpalis* lives on that of crocodiles, and Hodges, on that of hippopotami. Sir David and Lady Bruce studied the life-history of *G. morsitans*, which produce yellow-coloured larvæ, and are to be found as a rule near the roots of banana-trees. These larvæ are composed of twelve segments, the anterior of which carries the two minute mouth-hooks, and the posterior a dark hood or anal segment. The larvæ retire to some hole, and in a few hours become jet-black pupæ, from which the fully developed insects issue in about six weeks.

The pupa is 6·3 to 7 by 3 to 3·6 millimetres, with twelve segments. The anterior four show the longitudinal seam which bifurcates at the fourth segment, forming an opening through which the imago escapes. The first segment carries the mouth and the twelfth two lateral tumid, tuberculated lips, connected by dorsal and ventral ridges enclosing a pit, in which the posterior stigmata can be seen.

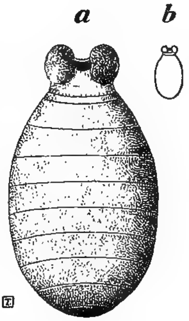

FIG. 248.—PUPA OF A TSETSE-FLY. (After Austen, from 'Tsetse-Flies.')

a, Magnified; *b*, natural size.

The larvæ of *G. palpalis* measure 4·5 by 1·75 millimetres, and the pupæ 5 to 5·75 by 3 millimetres.

Bionomics.—As *G. palpalis* is most probably the sole means of propagation of human trypanosomiasis, it is important to have some idea of what is known as to its bionomics, which have recently been carefully studied by Hodges and Bagshaw.

The main resort of the fly is to be found in bush near water, especially in the undergrowth composed of shrubs, bushes, vines, creepers, tall grass, cane-break tangle, and herbaceous plants. Tall trees alone will not afford the protection necessary for the fly unless they overhang the water, or their foliage reaches so low as to mix with the undergrowth.

The fly is, however, not met with behind a wide strip of papyrus, though it may be found on its water edge. This is explained by Bagshawe on the grounds that papyrus grows best in shallow water. which means that the ground is swampy, a condition which prevents the fly from depositing its larvæ. From a resort such as this a fly can travel for feeding purposes, or be carried by attraction or artificial means. It appears probable from Bagshawe's experiments that a single flight will not reach 70 to 80 yards, but flies can be carried to almost any distance by the agency of boats and floating islands of papyrus. Human traffic also increases the dissemination of the fly, as it is apt to pursue human beings for considerable distances.

Female flies appear to travel farther in search of food than males, probably because they more urgently require it. Bagshawe suggests that this can be made use of in finding the breeding-grounds, where he says plenty of males as well as females are to be found, while females alone may be met with at some distance therefrom. The feeding range, therefore, varies considerably.

Flies bite mostly during the middle part of the day, and not so much at dawn or in the late afternoon.

According to Hodges, the chief conditions required for a breeding-ground are loose, dry, friable earth, situate not more than 20 yards away from the high-water mark of a stream, and protected from sun and rain by the shade of trees and undergrowth.

Such conditions are found on steep banks along lakes, rivers, water-courses, etc., and the larvæ are to be looked for at the bases of shrubs and trees, in the undergrowth, and in earth-filled hollows in tree-trunks and branches at no great distance from the ground.

Bagshawe found the larvæ principally at the roots of bananas with scrub and water in the immediate neighbourhood; at the roots of a shrub called *Allophyllus*, belonging to the Sapindaceæ, especially in the dry season; at the roots of large figs and of the wild date-palm (*Phœnix reclinata*); while he also found a few pupæ in dry earth sheltered by overhanging rocks on wooded banks.

The breeding season appears to be at the commencement of the rains, as Bagshawe generally found empty pupal cases in the dry season.

The pupæ apparently have their enemies which eat them. These are minute winged insects probably belonging to the Chalcididæ, though this is not definitely known.

Classification.—Austen's classification, slightly modified, is as follows:

A. Hind tarsi entirely dark (female of *Glossina tachinoides;* basal half of first and extreme bases of succeeding joints pale).

I. Ground colour of abdomen ochraceous buff, with interrupted dark brown deep transverse bands and sharply defined pale hind borders to segments. A very conspicuous square or oblong pale area in the centre of the second segment. Small species: Body-length 7 millimetres—(1) *G. tachinoides* Westwood 1850.

II. Abdomen very dark; pale area in second segment usually triangular. Large species.

  1. Third joint of the antenna dusky brown to cinereous black—Body-length 8 to 9 millimetres—(2) *G. palpalis.* Robineau-Desvoidy 1830.
  2. Third joint of antenna pale. Body-length 8 to 9 millimetres—(3) *G. pallicera* Bigot 1891.

B. Hind tarsi not entirely dark.

I. Small species: 8 to 10 millimetres body-length. Length rarely 11 millimetres. Wing expanse not more than 25 millimetres.

  (*a*) Last two joints of front and middle legs with sharply defined dark brown or black tips.

    (1) Large species: Wide head, darker anteriorly; abdomina bands deep—(4) *G. longipalpis* Wiedemann 1830.

    (2) Smaller species: Narrower head—(5) *G. morsitans* Westwood 1850.

  (*b*) Last two joints of fore and middle tarsi pale. Body-length 8 to 10 millimetres—(6) *G. pallidipes* Austen 1903.

II. Large species: Body-length 11 to 13 millimetres. Wing expanse 25 millimetres at least.

  (*a*) Dorsum of thorax with four sharply defined small black spots—(7) *G. longipennis* Corti 1895.

  (*b*) Dorsum without spots—(8) *G. fusca* Walker 1849.

A species, *G. maculata,* is described by Newstead, but it may only be a variety of *G. palpalis.* It was described from only one damaged specimen, and Newstead says that it looks very like a dark specimen of *G. palpalis.*

MUSCINÆ.

Musca Linnæus 1761.

Musca domestica Linnæus 1761.

Musca: face in its lower part silky yellow, shot with blackish-brown. Median stripe black; antennæ brown; palpi black.

Thorax dusty grey, with four equally broad longitudinal stripes.

Scutellum grey, with black sides. Wings tinged pale grey with yellowish base. Legs blackish-brown. Abdomen yellowish, with dorsal blackish-brown line, except the last segment, which is entirely blackish-brown. Eyes separated by a wide frontal stripe in the female, and near together in the male. Length, 6 to 7 millimetres; wing breadth, 13 to 15 millimetres.

It has been known for many years that flies can carry micro-organisms on their legs. In 1888 Celli proved that flies, fed upon pure cultures of typhoid bacilli, were able to transmit virulent bacilli with their excrement. Early observations also proved that flies were capable of transmitting cholera. In the Spanish-American War, in the Army Concentration Camps of 1898, flies were found to be spreaders of typhoid. Lime was sprinkled on the fæcal pits, and the flies on the soldiers' mess-table were noticed to have their legs whitened with the lime.

The flies which breed in human excrement in America are: (1) *Musca domestica*, house-fly; (2) *Drosophila ampelophila*, fruit-fly; (3) *Fannia canicularis*, little house-fly; (4) *F. brevis*, little house-fly; (5) *Stomoxys calcitrans*, stable-fly; (6) *Phora femorata*; (7) *Sarcophaga trivialis*.

Of these the most common are the house and the stable flies. The house-fly is 98 per cent. of all flies infesting houses.

In the Boer War of 1900-02 flies were held to be great spreaders of typhoid. In 1902 a paper, entitled 'An Inquiry into the Influence of Soil, Fabrics, and Flies in the Dissemination of Enteric Infection,' was published by Firth and Horrocks in the *British Medical Journal*, and they showed that the ordinary house-fly (*Musca domestica*) can convey enteric infective matter from excreta or polluted materials, or objects on which they may walk, rest, or feed. Such infective matter appears to be attached to their heads (mandibles), legs, wings, and bodies. Klein has recently grown the typhoid bacilli from flies caught in an infected area.

Flies have long been accused of being the spreaders of dysentery, and recently this view has been experimentally proved by several authors, including one of us. Other diseases, including intestinal myiasis, are said to be spread by flies.

The flies found by Newstead in houses in Liverpool, or bred from refuse and excreta, were *Musca domestica* in quite 90 per cent. of all flies, while the other species met with were: *Calliphora erythrocephala*, the blow-fly; *Scalophaga stercoraria*, the dung-fly; *Borborus equinus*, a small fly; *Stomoxys calcitrans*, the stable-fly; *Fannia canicularis*; *F. scalaris*; *Anthomyia radicum*, the root-fly; *Psychoda phalænoides*, the owl-midge.

Morphology.—The vertex shows three ocelli, situated on a slightly raised ocellar triangle, which is surrounded by another triangle, the vertical triangle.

Between the upper and lateral edges of the clypeus (face) and the lower edge of the epicranium can be seen the crescentic opening of the ptilinum.

The proboscis consists of the rostrum, the haustellum (proboscis proper), and the labellæ. The rostrum is a truncated cone containing the pharynx; the haustellum is grooved anteriorly to contain the labrum, epipharynx, and the hypopharynx. Posteriorly it is strengthened by a sclerite called the 'theca,' which distally carries the fork (*furca*).

The labrum and the epipharynx, with the hypopharynx, as is usual, form the pharyngeal tube, while the hypopharynx contains the salivary or hypopharyngeal tube. The labellæ are complicated organs with a number of channels (pseudo-tracheæ) on their distal surface.

Each labellum has lobes anterior, middle, and posterior, with respectively twelve, twenty-one, and three channels, which eventually run to the oral aperture, which lies at the base of the oral pit. This pit is kept open by two discal sclerites. In the oral pit the pseudotracheæ cease, and the sides of the channels are covered by overlapping teeth.

The pro- and meta-thoraces are much reduced, while the mesothorax is well developed, and shows a typical structure. The venation of the wings may be briefly described by saying that the costa and subcosta are well marked, and the usual costal and first costal cells are present. Radius 1 cuts off the subcostal cell; R. 2 and 3 the first radial, and R. 4 and 6 the third radial; while Media 1 and 2 bound the radial and fifth radial cells, which are separated by the radio-median nerve. Median 3 and Cubitus 1 cut off the median and second median cells, which are separated by the medio-cubital vein. The anal vein is incomplete, and therefore does not separate the cubital and anal cells.

The abdomen consists of eight segments in the male, and nine in the female. The first segment in both sexes is rudimentary, and fused with the second. The second, third, fourth, and fifth are well developed. The sixth, seventh, and eighth in the male are atrophied, and surround the anal and genital orifices. The sixth, seventh, eighth, and ninth in the female form the long ovipositor, which can be retracted into the abdomen.

The pharyngeal tube mentioned above ends in the pharynx, which has a chitinous wall, the fulcrum. The œsophagus runs into the thorax, where it opens into the proventriculus, and sends a long duct to the trilobed crop which lies in the abdomen. The proventriculus is really a valve which leads to the chylific ventricle. This tube is narrow in front and wide behind, and much coiled. At the junction with the Malpighian tubes it becomes the intestine, which runs to the rectum. There are the four usual rectal glands.

The salivary glands are two long tubes whose ducts unite in the head and open into the salivary duct of the hypopharynx. The labial glands lie in the proboscis at the base of the labellæ, and by their secretion keep the tip moist.

The reproductive organs consist in the female of ovaries, spermathecæ, accessory glands and ducts, and the ovipositor. In the male they consist of testes, vasa deferentia, an ejaculatory duct, and penis.

The Life-History.—This was first studied by de Geer in 1752-78, next by Bouche in 1834, Packard, junior, in 1873, and more recently by ourselves and a number of other people. The most recent works are those by Newstead in Liverpool and Hewitt in Manchester.

The house-flies lay their eggs by preference in human fæcal matter when somewhat decomposed, in horse-manure, goat-manure, cow-dung, and in fermenting vegetable substance, on which the larvæ can feed when hatched.

But these grubs can eat textile fabrics and paper when in need of nourishment. Usually the fly works its way into the rubbish-heap or loose earth to lay its eggs, but this is not invariable.

The time required for the development to be gone through depends upon the temperature of the air, being most rapid from 22° to 35° C.; upon the food, being more rapid when animal food is available; on moisture, which is most necessary; and upon fermentation, which is also necessary. The egg takes from one to three days to hatch into the larvæ, which lives rather less than a week, and then turns into the pupa, which produces the imago.

The whole time required is usually twelve to twenty days, and never less than eight days.

Aldridge gives the following table for India:

Stage.		Hot weather.		Cold weather.
Eggs	..	One day	..	Two days.
Larvæ	..	Five days	..	Fourteen days.
Pupæ	..	Three days	..	Five days.

In Colombo, Ceylon, we found the development to be quick, and to resemble the times given in Aldridge's hot-weather table.

The imago becomes sexually mature in ten to fourteen days, and eggs are laid as soon as the fourth day after fertilization, usually 120 to 150 eggs being laid in a batch. The egg is cylindrically oval, being broader posteriorly, and has two curved ribs along its dorsal aspect. It hatches by splitting at the dorsal portion of the anterior end. The larval life is divided into periods or instars by the ecdyses.

First Instar.—The larva is 2 millimetres in length, with a slender body, the head being at the narrow end, with a spiny area on the anterior ventral edge of each segment, and posteriorly two stigmatal openings. This stage lasts twenty-four to thirty-six hours.

Second Instar.—The larva develops a pair of anterior spiracles. This stage lasts twenty-four hours.

Third Instar.—The larva eats vigorously for the first two days, and then, ceasing to feed, still increases in size. This stage lasts three to four days, and ends in pupation. The larva has a well-developed alimentary canal.

Pupation.—Pupation takes place in three to four hours, and consists of the larvæ contracting (especially anteriorly) inside its own skin, from which a puparium with rounded ends is formed, length about 6·3 millimetres, which is at first creamy yellow, but later becomes dark brown.

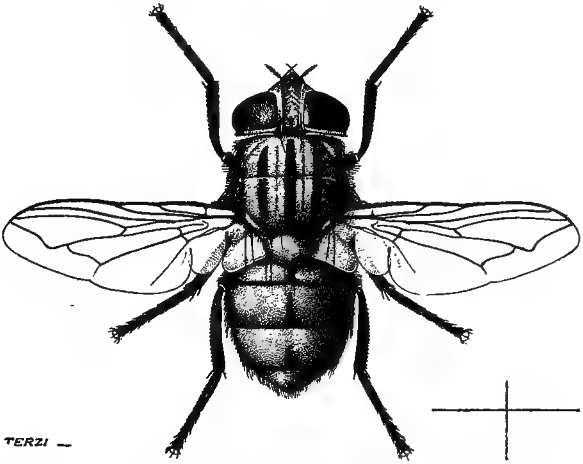

FIG. 249.—CHRYSOMYIA MACELLARIA (FEMALE). × 4.

This is a typical coarctate pupa, around which the spiral locomotory pads may be seen.

Pupa.—The pupal stage lasts about three to five days, when the imago, dilating its frontal sac, ruptures the anterior end into dorsal and ventral portions, the whole separating by a circular split at the sixth segment.

The young fly is at first underground or in the middle of a rubbish-heap, through the interstices of which it makes its way to the surface by the aid of its ptilinum or frontal sac. When first hatched it is rather grey in colour, and has to allow its wings to dry before it is able to fly.

Calliphorinæ Brauer.

Calliphora Robineau-Desvoidy 1830.

These are the blow-flies or bluebottles, of which *C. erythrocephala* Meigen, is the common species.

Row of bristles on the hypopleura.

Chrysomyia Robineau - Desvoidy 1830.

Chrysomyia macellaria Fabricius 1794.

Synonyms.—*Musca macellaria* Fabricius 1794; *Lucilia macellaria* R.-D., 1830; *L. hominivorax* Coquerel 1858; *Calliphora infesta* Philippi 1861; *C. macellaria* Jorge 1878; *C. anthropophaga* Conil 1878; *Compsomyia rubrifrons* Macquart; *Somomyia montevidensis* Bigot.

This fly lays its eggs on wounds and in the cavities of the body. The larvæ from these eggs are composed of twelve segments, armed with minute spines. They burrow into the tissues, consuming even bone if it comes in their way, and are therefore liable to produce fatal results. It is found in North and South America and the West Indies.

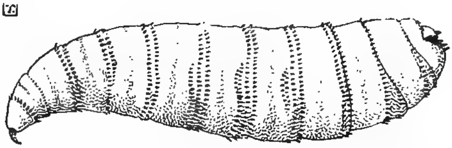
FIG. 250.—CHRYSOMYIA MACELLARIA (LARVA). × 4
(After Blanchard.)

Treatment.—Injections of chloroform water are the best means of getting rid of the larvæ, but the frontal and other sinuses may have to be opened to remove them if in large numbers.

Lucilia Robineau-Desvoidy 1830.

Flies of this genus—*e.g., L. cæsar* Linnæus and *L. sericata*—deposit their eggs on ulcers.

L. nobilis Meigen has been found in the auditory meatus. According to Peiper, *L. cæsar* Linnæus and *L. regina* Macy have been recognized as causes of intestinal myiasis.

Cordylobia.

Cordylobia anthropophaga Grünberg.

Synonym.—*Ochromyia anthropophaga* E. Blanchard.

The larva of this fly, which is called 'ver du Cayor,' because it was first noticed in Cayor, in Senegambia, burrows into the skin and causes a painful swelling. It extends from Senegal to Natal.

Life-History and Morphology.—It is not certain whether the fly lays its eggs upon the ground or upon the clothing of people and the skin of animals. Hence it is not known whether the larva creeps from the ground on to the human being or animal, or hatches in the clothing and simply enters the skin.

The larva, which measures about 12 millimetres, is composed of twelve segments, of which the anterior or cephalic is bluntly pointed in front and truncated behind, and carries two black mouth hooklets on its ventral surface. External to these hooklets lie the antennal protuberances. On the third to the eleventh segments there are minute, rather characteristic, brownish, chitinous, recurved spines. The greatest breadth is at the level of the sixth to seventh segments, while the last segment has a flattened posterior surface which carries the posterior stigmata. The pupa measures 10·3 by 4·6 millimetres, and looks like any ordinary muscid pupa.

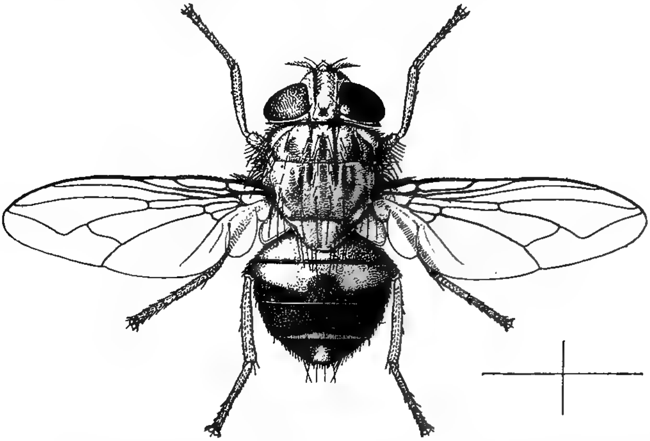

FIG. 251.—CORDYLOBIA ANTHROPOPHAGA (FEMALE). ×4.

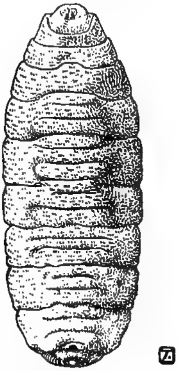

FIG. 252.—LARVA OF CORDYLOBIA ANTHROPOPHAGA. (After Austen.)

The fly measures 9·5 millimetres, and has a yellowish-coloured head, body, and wing. The thorax is marked dorsally by longitudinal dark stripes, while the abdomen has also blackish markings, and the wings are of a brownish tinge. The female is distinguished from the male by the eyes being separated by a broad frontal stripe; in the black colour of the third and fourth abdominal (except the margin) segments; and in the blackish quadrangular median patch on the second abdominal segment. In the male the eyes join. The larva is parasitic in men, monkeys, and dogs.

Lund's Larva.—Under this term a larva is described as occurring in the Congo Free State which possesses habits similar to those of *Cordylobia anthropophaga.*

Auchmeromyia.

Auchmeromyia luteola Fabricius 1805.

Synonym.—*Musca luteola.*

The larva of this fly is called the 'Congo floor-maggot.' It was found by Dutton, Todd, and Christy, living in the floor of native huts to the depth of 3 inches. At night these larvæ came out, and sucked the blood of persons sleeping on the ground, or on beds but little raised therefrom, but not on high beds.

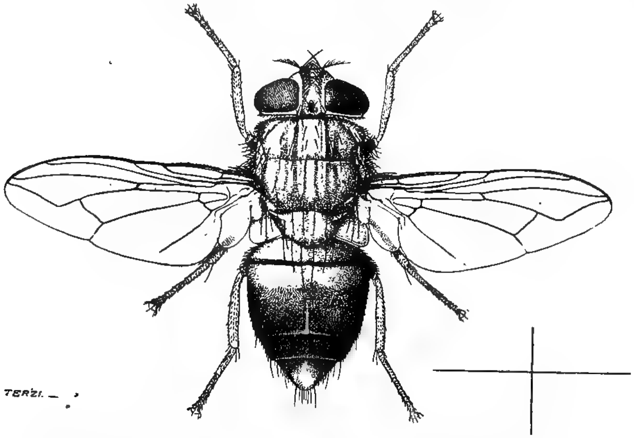

FIG. 253.—AUCHMEROMYIA LUTEOLA (FEMALE). × 3.

The native names for the larvæ are, 'Mabinzu,' 'Nchichi,' 'Ntunga,' 'Mvidi,' and 'Kiso.'

The Fly.—The fly is widely distributed in tropical and subtropical Africa. It is 10 to 12 millimetres in length, tawny in colour, with small black hairs giving it a smoky appearance. The head is large, as broad as the thorax. The eyes are separated by a considerable space. The proboscis is folded beneath the head into a deep groove. The palpi are club-shaped, with a long yellow, flattened, third joint, which carries an arista with black hairs on its upper and lower borders.

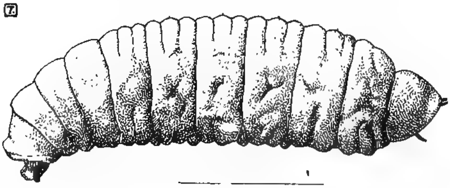

FIG. 254.—AUCHMEROMYIA LUTEOLA (LARVA). × 3.

The dorsum of the thorax is marked by longitudinal black and brown stripes, and shows a well-marked transverse suture. The squamæ are large, yellow in colour, and cover the halteres. The first abdominal segment has a narrow dark line posteriorly, the second a central median dark line, which joins with a posterior dark line. The third segment is dark brown, except for a narrow yellow anterior streak. The fourth segment is dark-coloured, with a posterior light brown band. The fifth segment is small, and contains the genital apparatus.

The legs are buff-coloured, with black hair and bristles. The fifth tarsal joint is jet-black, and has a large cream-white pulvillus.

Life-History.—The fly deposits its eggs on the ground of the hut, especially on spots on which urine has been voided. The larva is semitranslucent, of dirty white colour, acephalous and amphipneustic, and has eleven distinct segments. The first segment is divisible into two portions, of which the anterior carries the mouth parts. The broadest segments are the ninth and tenth. There are distinct dorsal and ventral surfaces, at the junction of which in each segment there are protuberances, with a spine and a pit. The ventral surface is flattened, and has three footpads transversely arranged at the posterior margin of each segment. The last segment is large, and carries the posterior spiracles and the anus.

The mouth, which is provided with teeth, leads into an œsophagus, which ends in a proventriculus, and has a dorsal diverticulum. The ventriculus is short. Malpighian tubules mark the commencement of the intestine. The hind gut is coiled. The salivary glands are well marked.

The larva becomes a dark brown or black pupa, 9 to 10·5 by 4 to 5 millimetres, with an anterior conical and a posterior rounded end, and marked by annular ridges. The pupal stage lasts two to three weeks.

Habits.—The fly does not bite man, only the larva as described above, which fills its dorsal œsophageal pouch with blood, and thus becomes of a red colour.

Pathogenesis.—As far as is known it is non-pathogenic.

Bengalia depressa Walker.

By an error this fly was said to cause cutaneous myiasis in Natal, Rhodesia, British Central Africa, Uganda, and the Sudan, the true causal agent being *Cordylobia anthropophaga* Grünberg. The life-history of *B. depressa* is unknown.

Oscinidæ Latreille 1804.

In Ceylon there is a curious little fly which hovers in front of the eyes, and is therefore commonly called the 'eye-fly,' which is an unknown species of the genus *Oscinus* Latreille 1804. This little fly is suspected after the experiments of Sir Allan Perry and Castellani to spread the Koch-Weeks bacillus, and to cause severe conjunctivitis.

Front without bristles, crown with only a few short ones, border of mouth without vibrissæ. Middle tibia with small spurs. Tibiæ without erect bristle on exterior side before tip. Costa of wings without bristles. Auxiliary vein wanting. Anterior of two small basal cells united with discal cell; posterior totally wanting.

Anthomyidæ Latreille.

Diptera with arista naked or pectinate. Thorax with complete transverse suture. First posterior cell completely open. Abdominal bristles often absent.

This family includes a number of genera known to be troublesome to man—*Fannia* Robineau-Desvoidy, *Hylemyia* Macquart, *Hydrotæa* Robineau-Desvoidy—which may be recognized by the following characters: (*a*) Arista bare—*Fannia*; (*b*) arista plumose—*Hylemyia*; (*c*) arista pubescent—*Hydrotæa*.

Fannia Robineau-Desvoidy 1830.

Fannia canicularis Linnæus 1761.

Synonyms.—*Homalomyia canicularis* Linnæus, *Anthomyia canicularis* Linnæus.

This species has frequently been reported as being passed in human fæces. The fly is commonly found in houses in Europe and North America. The larvæ normally live in vegetables, by means of which they enter the human digestive tract. They are provided with branched processes on the segments.

Pathogenesis.—Blankmeyer gives an account of a case of this infection which is said to have lasted some twelve years, being associated at first with abdominal pain, bloody diarrhœa, severe pains in the region of the liver. After the initial attack the pains continued, but instead of diarrhœa, constipation resulted, with severe headaches. The abdomen was distended.

The patient was treated with raw pumpkin seeds and then given a saline purge, and passed 1,000 to 1,500 *Fannia* larvæ. After this he still passed a few larvæ for some days, but eventually recovered. This is a curious case, in that the larvæ lived for years inside the man, and because it is not clear how such an enormous infection was possible. Recently Cheyril has collected and described seven authentic cases of myiasis of the urinary passages caused by the larva of this fly.

Fannia desjardensii Macquart.

Synonyms.—*Homalomyia desjardensii* Macquart, *Anthomyia desjardensii* Macquart.

Wellman describes cases of this myiasis in the alimentary canal of human beings in Angola who showed dysenteric symptoms, and which he successfully treated with castor-oil, then santonin, and then castor-oil again.

The disease is locally known as 'ovænyo,' a term which signifies maggots. The editors of the *Journal of Tropical Medicine* in 1907 asked for information with regard to an African myiasis called 'muculo,' but as far as we know this disease has not been traced. Wellman says that the term is not used in Angola. In *H. desjardensii* the larvæ become pupæ in seven to nine days, and the pupæ insects in another thirteen to fifteen days.

Other Species.—Peiper also lists *F. scalaris*, *F. incisurata*, *F. manicuta*, *F. saltatrix* as being causes of intestinal myiasis.

Hydrotæa Robineau-Desvoidy 1830.

Hydrotæa meteorica Linnæus, which usually attacks animals' eyes and nostrils, is said to attack man also.

Philæmatomyia Austen 1909.

Philæmatomyia insignis Austen 1909 is a biting fly found in India, Ceylon, Sokotra, Cyprus, Senegal, and the Congo Free State, and is remarkably like *Musca domestica*, but possesses a very remarkable biting proboscis, which consists of a strongly swollen chitinous bulb and a soft distal portion capable of being folded under the bulb when not in use and of being extended when in use. Its anterior or distal extremity is armed with a circle of strong chitinous teeth.

SUBORDER III. PUPIPARA.

Synonym.—*Eproboscidæ.*

The Pupipara are flies which appear to have become altered owing to their parasitic life. They possess a well-defined proboscis, which is said by Austen to resemble that of the *Glossinæ* by being armed at its tip with teeth. Wings have been lost in several species, either entirely or after the imago has become parasitic, though they may exist throughout life in other species. Their feet are provided with extra ungues to enable them to cling to the hairs, etc., of the host. They do not lay eggs, but produce a larva, which soon becomes a pupa.

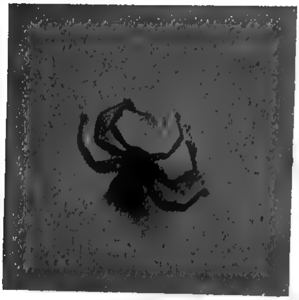
Fig. 255.—Nycteribia sp. [?]

The suborder is divided into four families: (1) Hippoboscidæ; (2) Nycteribidæ; (3) Braulidæ; (4) Streblidæ.

The Nycteribidæ are parasitic on birds, the Braulidæ on bees, and the Strebidæ on bats, and therefore will not be considered further.

HIPPOBOSCIDÆ.

Pupipara with horny flattened heads and bodies, and with one jointed antenna furnished with a terminal arista. The first joint of the tarsus is usually abbreviated in all, but certainly in the first two legs.

Wings may be well developed, or rudimentary, or entirely absent.

This family is composed of forms parasitic on mammals, and includes the following genera: *Hippobosca* Linnæus 1761, *Allobosca* Speiser, *Olfersia* Wiedemann 1830, *Pseudolfersia* Coquillett, *Lipoptena* Nitzsch 1818, and *Melophagus* Latreille 1804.

Hippobosca is parasitic on cattle, horses, dogs, etc., all over the world; *Allobosca* is parasitic on lemurs in Madagascar; *Ortholfersia* on kangaroos in Australia; *Lipoptena* on deer all over the world; and *Melophagus* on sheep.

Hippobosca rufipes von Olfers is thought to be capable of transmitting *Trypanosoma theileri*, which is the cause of galziekté in South African cattle.

Hippobosca equina Linnæus is known on horses in the New Forest, England, and *Hippobosca francilloni* Leach on dogs in Africa, India, Persia, and South Europe. *Melophagus ovinus* Linnæus is found all over the world, and in addition to these, *H. camelina* Leach and *H. maculata* Leach in the Sudan and Egypt.

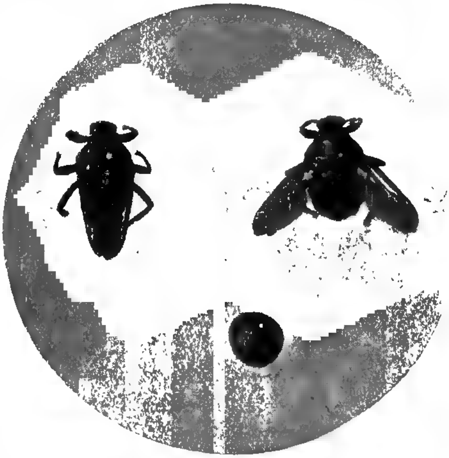
Fig. 256.—Hippobosca sp. [?] (Male, Female, and Pupa).

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CHAPTER XXI

BIOLOGICAL CAUSES OF DISEASE (*continued*) —SIPHONAPTERA AND RODENTIA

Siphonaptera—Sarcopsyllidæ—*Dermatophilus penetrans*—Pulicidæ—Pulicinæ—*Pulex irritans*—*Læmopsylla cheopis*—Coleoptera—Rodentia—Murinæ—*Mus rattus*—*Mus norvegicus*—References.

SIPHONAPTERA Latreille 1825.

Synonyms.—*Rophoteira* Schellenberg 1798, *Aptera* Lamarck 1801, *Aphaniptera* Kirby and Spence 1826, *Pulicidæ* Stephens 1829.

Diptera with laterally compressed bodies and distinctly separated thoracic rings. Wings absent, except for two lateral plate-like appendages on the meso- and metathorax.

The antennæ are three-jointed, and embedded in grooves. The third joint has nine more or less separated pseudo-joints.

Fleas have recently come into considerable prominence, owing to the work of the Indian Plague Commission and that of Dr. Verjbitski, of St. Petersburg, who have shown that they are to be looked upon as the main agents by which plague is spread from rat to rat, and from rat to man.

Fleas may also carry blood parasites—as, for example, *Trypanosoma lewisi*—and, again, they may serve as intermediary hosts for the cysticercus of tapeworms, as in the case of *Dipylidium caninum*.

The knowledge concerning fleas is of recent date. In 1758 Linnæus started with one genus and species, *Pulex irritans*; the second genus was that of the *Chigoe* in 1815, under the term *Rhynchoporion penetrans*; and the third genus was created by Curtis in 1832 under the heading *Ceratophyllus*. The first general systematic treatise was by Kolenati in 1863, the second by Taschenburg in 1880, and the third by Baker in 1904.

Recently much work has been done on these parasites by Rothschild and Jordan.

Morphology.—The head is small, and may or may not possess eyes, which, when present, are only simple pigment masses. Directly behind the head is the antennal groove, in which the antennæ, which are important organs to the flea, lie protected from harm. This groove is continued upwards to the mid-line of the vertex by an incrassation which divides the frons from the occiput. The groove may be open or closed by a process of the gena.

The antennæ are composed of three joints, of which the third, often called the club, may be unsegmented, segmented on the posterior border only, or completely segmented into nine more or less separate pseudo-segments.

The frons may carry a tubercle or notch, situate rather nearer the mouth than the centre of the head, while laterally the eyes, when present, are to be seen. The area of the head below the eyes and extending from the perioral ring to the antennal groove is the gena. A process of this area may be prolonged backwards, so as to meet the hind edge of the post-antennal part of the head, and so to close the antennal groove below in those species which possess a closed antennal groove.

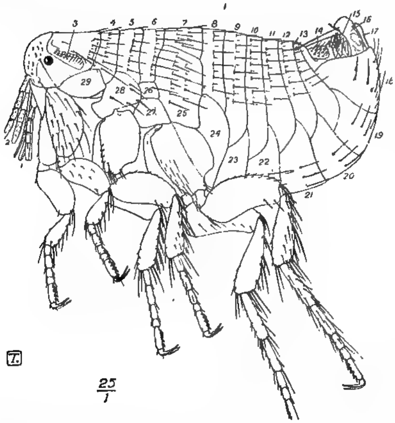

FIG. 257.—LŒMOPSYLLA CHEOPIS (MALE).

(After Jordan and Rothschild, *Journal of Parasitology*.)

1, Labrum, mandibles, and labial palps (at the junction of the last named with the head is seen the triangular maxilla); 2, maxillary palpi; 3, antenna; 4, pronotum; 5, mesonotum; 6, metanotum; 7-12, ordinary abdominal tergites; 13, seventh tergite with bristle (behind this is seen the small eighth tergite); 14, ninth tergite, with sensory plate; 15, tenth tergite; 16-24, sternites of abdominal segments; 25-27, metasternite; 28, mesosternite; 29, prosternite.

The occipital area carries usually three rows of bristles, the first near the base of the antennæ, the second in the middle, and the third near the hinder edge of the head, which are continued forwards on to the frons, and probably delineate the four segments of which the head is composed.

Anterior and ventral to the frons and gena lies the perioral ring, which carries the mouth appendages, which consist of a labrum (epipharynx), mandibles, maxillæ, and palps, hypopharynx, and labium with palps. There does not appear to be a separate clypeus.

The labrum (variously known as epipharynx, hypopharynx, and by other names) is a hollow prolongation of the dorsal wall of head and pharynx. In front it is closed, while behind it opens into the cœlom. Ventrally it shows a groove, converted into a canal when it is articulated with the mandibles laterally. The mandibles consist of basal segments attached to the sides of the mouth, and an anterior portion which projects freely forwards, and shows fine serrations anteriorly. The inner aspect of the mandibles possesses a groove, converted into a trilobed channel by articulation with the fellow of the opposite side and the hypopharynx.

The maxillæ are triangular chitinous plates, each possessing a four-jointed maxillary palp. The labium (which, of course, represents the second maxillæ with their palps) is single posteriorly, where it is attached to the perioral ring, while in front it is divided into two one-to-thirteen jointed palps (labial palps), which form a sheath or rostrum for the other mouth parts.

The hypopharynx consists of a basal portion, which is a chitinous plate concave ventrally, extending forwards in the head from the infra-œsophageal ganglion to the mandibulo-basal articulation, and an anterior portion, which projects from the basal portion forwards, and contains the canal from the salivary pump.

This anterior portion of the hypopharynx articulates laterally with the mandibles, and its canal, opening ventrally, forms the triradiate canal mentioned above, which is continuous with the salivary groove on the mandibles.

The thorax is composed of the usual three divisions, but there are no signs of scutellum or post-scutellum. There is generally one, but there may be two or three rows of bristles on each segment. The pronotum may have a comb. The metanotum may be dentate or serrate apically. Laterally the metathorax is typical, showing a sternite, episternite, and epimerite, while the mesothorax shows a sclerite, divided into two by an internal incrassation running from the coxa upwards. These two divisions represent the episternite and the epimerite. The episternite has the anterior and ventral portion separated off by an oblique incrassation to form a sternite. The prosternite, or sternite of the prothorax, is not divided. Generally these various sclerites show bristles.

With regard to the abdomen, the first to seventh segments are more or less normal, but the eighth to tenth are modified sexually. The tergites of the second to the seventh segments are normal, carrying bristles and combs in different species. The seventh tergite has a subapical bristle. The first segment has no sternal sclerite, hence the first visible sternite belongs to the second segment. The third to the sixth sternites carry a ventral row of bristles. The seventh has a considerable number of bristles. The sexually different segments must be considered according to sex. In the female the eighth tergite is very broad ventrally, but the sternite is reduced to an elongated plate lying between the ventral edges of the tergite.

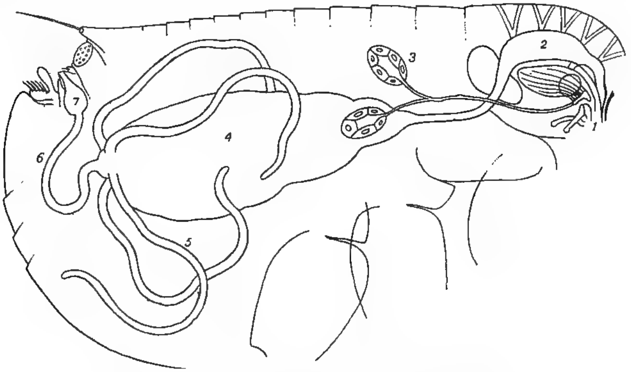

Fig. 258.—Anatomy of a Flea.

(From the *Journal of Hygiene*, 1906.)

1, Mouth; 2, pharynx; 3, salivary glands; 4, stomach; 5, Malpighian tubes; 6, intestine; 7, rectum.

The ninth tergite carries the sensory plate, with usually fourteen (there may be more) setiferous grooves. The ninth sternite is membranaceous laterally, and extends far ventrally, where it is strongly chitinized, and lies inside the seventh or eighth segment. It forms the ventral wall of the vagina, which is joined just anterior to it by the duct of the receptaculum seminis.

The tenth tergite carries a short conical stylet, while the sternite, which is triangular, carries a long bristle ventrally before the apex and shorter bristles at the apex.

The eighth tergite of the male is small, while its sternite is large, and from its cavity the copulatory organs project. The accessory genital organs belong to the ninth segment, the sides of whose tergite form the clasping organ laterally. The internal ventral angle of the clasper is prolonged into a manubrium, above which is a tubercle-like projection. The outer side of the clasper has three processes, which are different in *Pulex* and *Lœmopsylla*. The ninth sternite has an internal vertical arm and a ventral horizontal arm. The latter appears beyond the eighth sternite. The penis can be seen between the ninth sternite and the claspers.

Internal Anatomy.—The mouth, which is situate below the base of the labrum, opens into the aspiratory pharynx, which communicates, viâ a long œsophagus, with the stomach. Just before this organ the œsophagus is swollen into a bulb, which represents the proventriculus.

At the junction of the stomach with the intestine are the openings of the four Malpighian glands. The intestine is divided into small intestine, colon, and rectum, the last mentioned opening at the anus.

The salivary apparatus is, as usual, separate from the alimentary canal. It consists of two glands, on each side of the body, lying in the fat-body in front of the stomach. The duct from each gland joins, forming a common duct on each side, which runs forward to open into the salivary pump. This is a hollow, chitinous organ, supplied with powerful muscles, situated at the anterior end of the ventral surface of the hypopharynx.

The duct of this pump, running forwards through the hypopharynx, opens viâ the triradiate canal already mentioned as formed by the junction of the hypopharynx with the mandibles, into the groove of these organs.

The Act of Biting.—The flea apparently carefully selects the spot at which it is to bite, and then pierces a hole by means of the labrum. This hole is then enlarged by the mandibles, through whose grooves salivary secretion is pumped into the skin. This secretion irritates the vessels, causing a local rush of blood to the part, and this blood is drawn by the suction of the pharynx up a tube formed by articulation of the labrum with the mandibles. This tube, of course, is embedded in the skin, which is pierced by its two component parts.

There are therefore two tubes in the mouth-parts of a flea—an efferent, carrying the salivary secretion, and an afferent, carrying the blood, which is taken to the stomach, and hæmolyzed and digested. It appears that the black residual mass is capable of further digestion by the rectal glands. Further bionomics will be given under *Lœmopsylla cheopis*.

Life-History.—The egg is oval, waxy white or opaque porcelain in appearance, smooth, and with a length of about 0·5 millimetre. It is generally deposited between the hairs of the host, and falls off on to the ground. In two to four days the larva is hatched. This larva is an elongated, worm-like little creature with fourteen segments. The head is well developed, and has strong mandibles suitable for biting. It lives on dead organic matter, and moults three times as a rule—*i.e.*, three to four days, and again six days, and again seven to fourteen days after hatching. It then spins a cocoon, inside which the pupa becomes the imago in about five days, the whole time required for development being fourteen to thirty-three days.

Dispersal.—Fleas are dispersed mainly by their host travelling about. Such a host as a rat may, of course, be carried by merchandise, and, again, merchandise itself can spread fleas.

Capture of Fleas.—If it is desired to capture fleas, allow a suitable animal to remain in the place, when the fleas will gather on it.

Then chloroform the animal, and comb the stupefied or dead fleas on to white paper.

Remedies.—The remedies for fleas are, first and best, a clean house—*i.e.*, plenty of soap and water applied to the floors, etc. Otherwise pyrethrum powders and benzene may be used.

A flea cannot jump more than 4 inches—an important fact to be noted.

Flea larvæ are delicate little things, and cannot stand disturbance; hence fleas will not be found in houses kept well swept and dusted, but will abound in infected empty houses.

Classification.—The Siphonaptera are classified by Rothschild into three families: (1) Sarcopsyllidæ, (2) Pulicidæ, (3) Ceratopsyllidæ.

Only the first two are of importance, the last named being found on bats.

FAMILY SARCOPSYLLIDÆ Taschenburg 1880.

Synonym.—*Rhynchoprionidæ et Hectopsyllidæ* Baker 1905.

Siphonaptera without ctenidia. Labial palps rather long, but very weak and fragile; pale, slightly chitinized, formed of one or two segments. Small maxillæ little prominent. Piercing apparatus very developed; mandibles large and strong. Genal extremity always prolonged below and in front into a process, placed behind the insertion of the mandibles. Nota of thoracic segments shorter than that of the first abdominal.

Genera.—*Echidnophaga* Olliff 1886, *Hectopsylla* Frauenfeld 1860, *Dermatophilus* Guérin 1838 or 1839, which, according to Jordan and Rothschild, may be recognized in the following manner:

I. Hind coxa with patch of spines on inner side—*Echidnophaga.*

II. Hind coxa without such a patch of spines:

(*a*) Hind femur with large basal tooth-like projection—*Hectopsylla.*

(*b*) Hind femur simple—*Dermatophilus.*

But of these we need only consider *Dermatophilus.*

Dermatophilus Guérin 1838.

Synonyms.—*Rhynchoprion* Oken 1815, *nec* Hermann 1804, *Sarcopsylla* Westwood 1836.

This genus contains the species *Dermatophilus penetrans* Guérin, distinguished by having a distinct eye, and *D. cæcata* Enderlein 1901, with a rudimentary eye. The latter species was found behind the ear of *Mus rattus* in Brazil.

Dermatophilus penetrans Guérin 1838.

Synonyms.—*Pulex minimus cutem penetrans* Catesby 1743, *Pulex minutissimus nigricans* Barrère 1743, *Acarus fuscus sub cutem nidulans proboscicæ acutiore* P. Brown 1756, *Pulex penetrans* Linnæus 1767, *Rhynchoprion penetrans* Oken 1815.

This is the insect variously known as the *Chigoe*, or jigger, and believed to have been discovered by Oviedo in 1551. The home of this little insect appears to be South America, especially Brazil, from which it was conveyed to West Africa about the middle of last century, arriving on the West Coast at Loanda from Rio Janeiro by a ship, the *Thomas Mitchell*, in 1872, whose crew was suffering from jiggers. It was probably noted on the Gold Coast for the first time in the early seventies. It appears to have spread across Africa by Stanley's Expedition and by trade routes, arriving in East Africa in 1895, and from East Africa it spread to India in 1899 by the 4th Bombay Infantry, but luckily the infection did not spread beyond Bombay. In 1900 it reached Madagascar. It affects not merely man, but domestic and wild animals. Perhaps the most noted feature is the way in which it attacks pigs. On the Gold Coast it appeared to be largely kept in existence by these animals. It is very easily captured in the free state by taking a little pig with a pale abdomen, and placing it on its back on the ground on which infected pigs are living. After watching a few moments, a black speck will appear on the pig's abdomen, and quickly another and another. These black specks are jiggers, which can easily be transferred to a test-tube. On examination, they will be found to be males and females in about equal numbers. It appears likely that a number of different species, if not genera, are included under the term *D. penetrans*, and there is

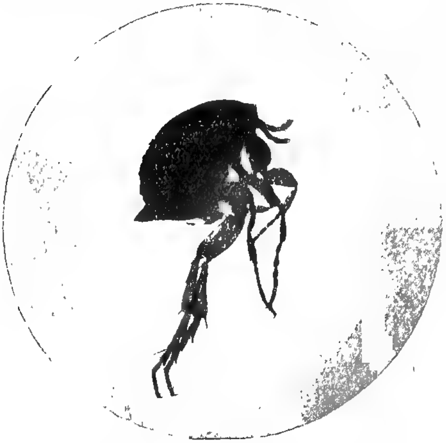
FIG. 259.—DERMATOPHILUS PENETRANS (MALE).

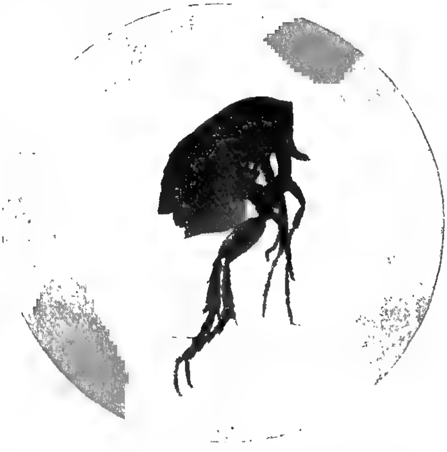
FIG. 260.—DERMATOPHILUS PENETRANS (FEMALE).

without doubt room for investigation into jiggers taken from wild and domestic animals and man.

If the reader will look at the list of synonyms, it will be clear that, by the law of priority, the name of this little insect should be *Rhynchoprion penetrans*, and not *D. penetrans*, as the name *Rhynchoprion* Oken is dated 1815; but Rothschild has recently pointed out that *Rhynchoprion* was applied in 1804 by Hermann to a tick, and also by Oken to other ticks in 1815.

Geographical Distribution.—It occurs in Mexico, West Indies, Central and South America, through the whole of Tropical Africa, and as far south as Mashona—*i.e.*, 30° N. to 30° S. In Asia it does not appear to flourish; it has only infected Bombay, and will probably not become naturalized, as the monsoon conditions do not appear good for it, for it flourishes in a warm, dry, sandy soil.

The female only becomes endoparasitic, and when it first arrives in a place, and is unknown, may cripple people, and cause loss of one or more toes.

Morphology.—The general account already given of the morphology of fleas and the special characters indicate the morphology sufficiently for the purposes of this book.

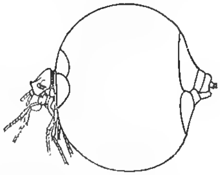

Fig. 261.—Dermatophilus penetrans (Pregnant Female).

Life-History.—The males and females live in dry, sandy soil as reddish-brown little insects about 1 millimetre in length, and are very active. They live by sucking the blood of warm-blooded animals. When impregnated, the female burrows into the skin of a warm-blooded animal, whether bird or mammal.

The abdomen now swells enormously into the size and appearance of a small pea. If one of these small peas is examined, it will be seen to show the head and thorax anteriorly, and the two last abdominal segments posteriorly.

The head is in the bottom of the burrow in the skin, and the posterior abdominal segments block the opening.

The eggs are expelled through the opening in the skin, after which the female jigger is expelled by ulceration. The egg develops into a larva with thirteen segments, which spins a cocoon, inside which is the pupa, which gives rise to the imago in about eight to ten days.

Pathogenesis.—This will be described later (Chapter LVI.), but it may be mentioned that it includes irritation, pus formation, ulceration, and formation of a sore, which may become infected with bacteria, and cause loss of a toe or a leg, or even tetanus may develop.

FAMILY PULICIDÆ Stephens 1829.

Siphonaptera with body compressed or elongated, always larger than in the preceding family. Head, in comparison to the rest of the body, small; top round; venter protected with hairs; often no eyes. The antennal groove is at times covered by a chitinous plate.

The end segment of the antenna is either segmented or unsegmented. Thorax wide; pronotum often with ctenidia. Abdomen never so swollen that the original form is lost. Female never endoparasitic.

There are three subfamilies: Pulicinæ Tiraboschi, Typhopsyllinæ Tiraboschi, Hystrichopsyllinæ Tiraboschi.

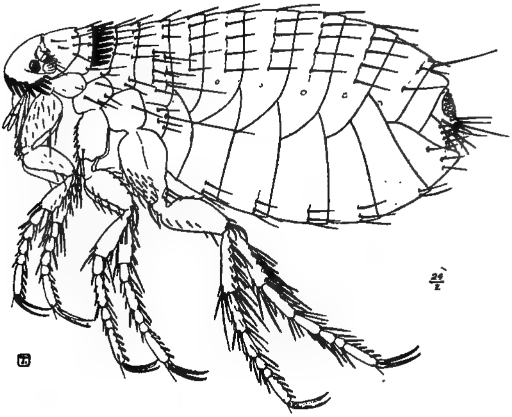

FIG. 262.—CTENOCEPHALUS FELIS BOUCHÉ

This drawing shows the combs on the head and prothorax.

SUBFAMILY PULICINÆ.

Pulicidæ with eyes.

The genera of the Pulicinæ may be arranged as follows (modified after Jordan and Rothschild):

- A. Ctenidia on head and prothorax—(1) *Ctenocephalus.*
- B. Ctenidia on prothorax only—(2) *Ceratophyllus.*
- C. Ctenidia absent.
  - I. Terminal segment of antennæ short, only distinctly segmented posteriorly. Hind coxa with a comb; fifth tarsal segment with four lateral and one subapical bristle.
    - (1) Forms with small mesial tubercle—(3) *Moeopsylla.*
    - (2) Forms without small mesial tubercle:
      - A. Mesosternite with internal rod-like incrassation from insertion of the coxa upward.
        - (*a*) Anterior angle of genal edge prolonged backwards into a triangular lobe; pronotum stronger than metanotum —(4) *Pariodontis.*

(*b*) Anterior angle of genal edge not produced into triangular lobe—(5) *Lœmopsylla.*

B. Mesosternite without internal rod-like incrassation from insertion of the coxa upward—(6) *Pulex.*

II. Terminal segment of antennæ segmented all round; hind coxa without a comb; fifth tarsal segment with four lateral bristles and one subapical hair.

(1) Terminal segment of antennæ symmetrical; genal process with a number of brsitles—(7) *Parapsyllus.*

(2) Terminal segment of antennæ asymmetrical; proximal segments sloping backwards. Genal process with only one to two bristles—(8) *Phopalopsylla.*

III. Terminal segment of antennæ segmented all round; symmetrical. Hind coxa without comb. Fifth tarsal segment with five lateral bristles at least, and subapical hair.

(1) *Antennal Groove Open Behind.*

(*a*) Abdominal tergites with one row of bristles, except first, which bears two. First hind tarsal segment shorter than second—(9) *Coptopsylla.*

(*b*) Abdominal sternites with very numerous short bristles. First mid-tarsal segment longer than second—(10) *Goniopsyllus.*

(2) *Antennal Groove Closed Behind.*

Abdominal tergites with one row of bristles —(11) *Lycopsylla.*

SUBFAMILY TYPHOPSYLLINÆ.

Pulicidæ with eyes absent or very rudimentary. Head rounded in front. Body thin.

Genera. — *Ctenopsylla, Stephanocircus, Typhopsylla, Neopsylla, Typhloceras.*

SUBFAMILY HYSTRICHOPSYLLINÆ.

Abdominal tergites with one or more ctenidia; posterior tibial spines in numerous short, close-set, transverse rows on posterior border, with about four spines in each row; female with four antepygidial bristles on each side.

Genera.—*Hystrichopsylla, Macropsylla.*

THE FLEAS OF RATS AND MICE.

Tiraboschi gives the following table of the fleas observed on rats, mice, and field-mice:

- Pulicidæ
  - Pulicinæ
    - Pulex
      - P. irritans L.
    - Lœmopsylla
      - L. cheopis Roth.
    - Ctenocephalus
      - Ct. felis Bouché.
      - Ct. canis Curtis.
    - Ceratophyllus
      - Cer. fasciatus Bosc.
      - Cer. londiniensis Roth.
      - Cer. consimilis Wagner.
      - Cer. mustelæ Wagner.
      - Cer. lagomys Wagner.
      - Cer. penicilliger Grube.
      - Cer. walkeri Roth.
      - Cer. pinnatus W.
      - Cer. gallinæ Sch.
      - Cer. abantis Roth.
      - Cer. lucifer Roth.
      - Cer. pollionis Roth.
      - Cer. agilis Roth.
      - Cer. californicus Baker.
    - Odontopsyllus
      - Od. charlottensis Baker.
      - Od. telegoni Roth.
    - Pygiopsylla
      - Pyg. colossus Roth.
  - Typhlopsyllinæ
    - Ctenopsylla
      - Ct. musculi Dugès.
      - Ct. spectabilis Roth.
      - Ct. taschenburgi W.
      - Ct. aganiffies Roth.
      - Ct. ellobius Roth.
      - Ct. pectuniceps W.
      - Ct. selenis Roth.
    - Stephanocircus
      - St. thomasi Roth.
      - St. dasyuri Skuse.
      - St. simsoni Roth.
    - Typhlopsylla
      - Typhl. assimilis Tasch.
      - Typhl. agyrtes Heller.
      - Typhl. pseudogyrtes Baker.
      - Typhl. prosuma W.
    - Neopsylla
      - N. bidentatiformis W.
      - N. pentacanthus Roth.
      - N. isacanthus Roth.
    - Typhloceras
      - Typhl. poppei Wag.
  - Hystrichopsyllinæ
    - Hystrichopsylla
      - Hystr. tripectinata Tirab.
      - Hystr. talpæ Curtis.
      - Hystr. narbeli Galli-V.
    - Macropsylla
      - Macr. hercules Roth.
  - Sarcopsyllinæ
    - Dermatophilus
      - D. penetrans L.
      - D. cæcata Enderlein.
    - Echidnophaga
      - Ech. rhynchopsylla Tirab.
      - Ech. gallinacea Westw.

Of these, the following are found on—

Mus norvegicus.

Pulex irritans Linnæus, *Læmopsylla cheopis* Rothschild, *Ctenocephalus felis* Bouché, *C. canis* Curtis ; *Ceratophyllus fasciatus* Bosc, *C. londiniensis* Rothschild, *C. consimilis* Wagner, *C. lagomys* Wagner, *C. mustelæ* Wagner, *C. penicilliger* Grube, *Ctenocephalus musculi* Dugès, *Neopsylla bidentaliformis* Wagner.

Mus norvegicus is the true host of *Ceratophyllus fasciatus.*

Mus musculus.

Ceratophyllus fasciatus Bosc, *C. londiniensis* Rothschild, *C. walkeri* Rothschild, *Odontopsyllus charlottensis* Baker (?), *Ctenocephalus serraticeps* Taschenburg, *C. musculi* Dugès, *Typhlopsylla assimilis* Taschenburg, *T. agyrtes* Heller, *Hystrichopsylla tripectinata* Tiraboschi.

Mus rattus.

Pulex irritans Linnæus, *Læmopsylla cheopis* Rothschild, *Ctenocephalus felis* Bouché, *C. canis* Curtis, *Ceratophyllus fasciatus* Bosc, *C. londiniensis* Rothschild, *Ctenopsylla musculi* Dugès, *Dermatophilus cæcata* Enderlein, *Echidnophaga rhynchopsylla* Tiraboschi, *E. gallinacea* Westwood.

Of all these fleas, the most important with regard to plague are :

A. Spreading the disease from rat to rat—*Læmopsylla cheopis* Rothschild and its allies ; *Ceratophyllus fasciatus* Bosc and its allies ; *Ctenopsylla musculi* Dugès ; *Ctenocephalus felis* Bouché ; *C. canis* Curtis.

B. Spreading the disease from rat to man—*Pulex irritans* Linnæus, *Læmopsylla cheopis* Rothschild, *Ctenocephalus felis* Bouché, *C. canis* Curtis, *Ceratophyllus fasciatus* Bosc.

Of all these, the most important is *Læmopsylla cheopis* Rothschild, and it is believed that its true host is *Mus rattus.*

Pulex Linnæus 1758.

Pulicinæ with head without notch on the frons ; antennal groove closed behind by a genal process. Strong incrassation separating occiput and frons. Eye large, a little pointed below, with two bristles beneath it, and one on the oral edge. Anterior angle of genal process projecting somewhat downwards, and usually bearing a small tooth (remains of a comb). Anal coxa is pear-shaped, carrying a number of hairs on the inner posterior portion, as well as in front, and carrying a row or patch of short spines near apex. Greatly reduced thorax, the tergites being short, each with a row of bristles, but without subapical spines on the mesonotum. Mesosternite characteristic, very narrow, with ventral edge close before apex, stigmata not being entirely covered. No internal rod-like or cariniform incrassation from the insertion of the coxa to the dorsal edge.

Male with eighth tergite with small manubrium; clasper with very large flap, on inside of which are two processes, forming a kind of claw. Manubrium of clasper large, curved. Ninth sternite boomerang-shaped, with its upper end pointed. Internal wire-like spring of ninth sternite and penis making several coils.

Female.—No hairs above stigma of eighth stergite. Stylet with long apical bristle and short bristle near apex. Anal sternite truncate; bristles confined to the apical edge.

Only species, *P. irritans* Linnæus.

Pulex irritans Linnæus 1758.

Synonyms.—*Pulex vulgaris* Raius 1710, *P. ater* Linnæus 1746, *P. hominis* Dugès 1832, *P. simulans* Baker 1895, *P. dugesi* Baker 1904.

This, in a much restricted sense, is the *P. irritans* of Linnæus, which included all fleas, but now the term is restricted to the parasite of man. It is essentially an Old-World flea, those of America being but distantly connected, but has now become cosmopolitan through trade. It appears to have been introduced into the eastern tropics by European trade. It is absent from the Sahara and the Haussa countries south of it, but it abounds all through Africa where there are European settlements.

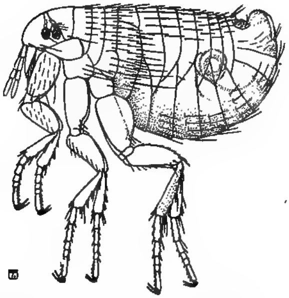

FIG. 263.—PULEX IRRITANS (MALE).

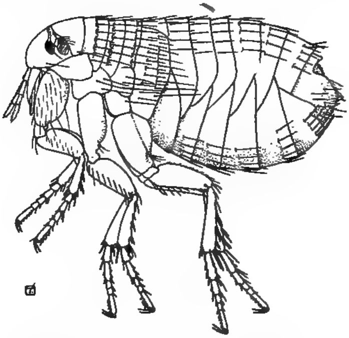

FIG. 264.—PULEX IRRITANS (FEMALE).

The question whether there are different varieties on the different races of mankind is not settled. Baker described a *Pulex dugesi* or *P. irritans dugesi* from West Mexico on *Citellus macrourus* and man, but is the only person who indicates this.

P. irritans is also found on animals, particularly the badger (*Meles taxus*) in England; on dogs, cats, rats, and other animals in various parts of the world.

Lœmopsylla Jordan and Rothschild 1908.

Pulicinæ with third segment of antennæ distinctly segmented only on posterior side. Eye round; one bristle below, one in front of eye, third at oral edge. Frons without tubercle; four-segmented labial palpus ; closed antennal groove. Pleura of the mesosternite divided by a suture into an episternite and an epimerite, with the dorsal apical bristle of the seventh abdominal tergite remote from the edge of the segment, with short spines on the inner surface of the coxa of the third leg, with a rod-like incrassation on the inside of the coxa of the second leg ; fifth tarsal segment with four lateral bristles besides the subapical hair.

Male with clasper provided with two or three small processes ; manubrium narrow ; upper internal portion of the ninth sternite not very sharply defined.

Female with the stylet bearing, besides the long apical bristle, a short bristle situated in a notch before apex.

Type.—*Lœmopsylla cheopis* Rothschild. This genus is found in Africa and Central Asia in particular.

At the time of writing there are some twenty-four species known.

Lœmopsylla cheopis Rothschild 1903.

Synonyms.—*Pulex cheopis* Rothschild 1903, *P. brasiliensis* Baker 1904, *P. murinus* Tiraboschi 1904, *P philippinensis* Herzog. 1904.

This is the rat-flea in all parts of the tropics, and is believed to be the principal transmitter of bubonic plague from the rat to man. Its home is believed to be the Nile Valley, where it lives on various hosts, but it has spread from there by the agency of the rats.

It is often referred to in literature by the name *P. pallidus* Taschenberg, which is really a different species.

Jordan and Rothschild report it on man or animals from the Egyptian Sudan, Pretoria, Beira in East Africa, Entebbe, Uganda, Benguella, Angola, Réunion, Marseilles, Plymouth, Aden, Bombay, Agra, Arabia, Japan, West Australia, New South Wales, Colombia, Paraguay.

They have found it on man, *Mus norvegicus, M. rattus, M. chrysophilus,* and several other animals.

Morphology.—Episternum of metathorax separated from sternum. The latter carries a bristle as long as that on the former. Hind femur angulate ventrally at the widest part. Fifth segment of fore- and mid-tarsi, with three spine-like bristles, ventrally at apex ; lateral ones very stout in male. Clasper with two distinct free processes ; manubrium long. Penis without a brush near apex.

Life-History.—The eggs are round, waxy-white or pearly in colour, and number one to five at each oviposition. They hatch in Bombay in two days, and produce the little larvæ, which at once hide themselves away from the light. In about a week's time these larvæ, which at first are very active, become sluggish, and, ceasing to eat, spin cocoons composed of fine white silk-like fibres. The cocoon becomes covered with rubbish, and is hard to see. In about seven to fourteen days the imago escapes from the cocoon. The total development, therefore, requires about twenty-one to twenty-two days.

Bionomics.—The young flea is capable of living without a feed of blood for some seven to fourteen days, but if not fed then it dies.

The length of life of a flea is difficult to ascertain, but *Lœmopsylla cheopis* will live forty-one days on a rat and twenty-seven days on a man. Therefore, the whole life of a rat-flea from birth to death is about sixty-three days. A rat-flea is more readily attracted by a rat than by a man. It breeds at all temperatures, but has one given optimum temperature above and below which it does not thrive so well. Dampness is injurious to the flea, killing the larvæ and hindering development.

L. cheopis is the commonest rat-flea, being probably the flea of *Mus norvegicus* in India, while in Western Europe *Ceratophyllus fasciatus* is the flea of the same rodent. It is found on *M. norvegicus*, *M. rattus*, and *Nesokia bengaliensis*; also on musk-rats, guinea-pigs, cats, rabbits, antelopes, kangaroos, and men.

The infection with plague bacilli does not appear to affect the flea's health, for it has an immunity, dependent, apparently, on phagocytosis.

COLEOPTERA.

Hexapoda with biting mouth-parts. Anterior wings altered to form cases for the thin posterior wings.

The larvæ of beetles have rarely been recorded as parasites of the alimentary canal, or found in abscesses in man in the temperate and tropical regions.

VERTEBRATA—MAMMALIA—RODENTIA.

Family Muridæ; subfamily Murinæ.

The Murinæ include the rats and mice, of which two are of great importance in the spread of plague—viz., *Mus rattus* and *M. norvegicus*.

Mus rattus.

Slender rats with very pointed muzzles and large out-standing ears, large prominent eyes, long tail, and greyish black fur.

The tail, which is 25 per cent. longer than the length of the head and body together, is brown and regularly annulated. Feet medium-sized, but comparatively long and slender.

Body variable, 14 to 19 centimetres in length. Colour variable: light rufescent, brown on the dorsum, white or grey on the venter, but may be darker or lighter. Mammæ $\frac{2}{3}$.

There are two varieties of this rat: *alexandrinus*, which is larger and heavier, and *rufescens*, which is smaller and redder; but there are any number of intermediate species. It breeds frequently throughout the year.

It is essentially a house-rat, living in the tiles or thatch of the roof, or in holes and recesses in the floor, but it will live in the crowns of cocoanut-trees.

Its pathogenesis is important, for it is the plague-rat of Upper India. It is supposed to have entered Europe with the Asiatic invasion.

Mus norvegicus.

Large, heavy rats, with heavy, uniformly tapering tails; dark-coloured dorsally, lighter-coloured ventrally; only 89 per cent. of the length of the head and body. Heavy, flesh-coloured feet, short round ears, and broad, heavy snout.

Colour: brown on the dorsum and dirty white on the venter. Foot-pads large; heart-shaped mammæ 10-12 in number.

This is the brown, sewer, or ship rat, which is supposed to have come from China to Europe, and from Europe to India. It is the plague-rat of Bombay. It is very prolific, producing several litters of 8-10 young per annum.

Destruction of Rats.—The destruction of rats may be brought about by natural enemies, such as owls and cats, etc., by traps, or by poison, but none of these methods work rapidly on a large scale; therefore attempts have been made to obtain some bacterium which will produce a fatal disease capable of being spread from rat to rat without being pathogenic to man and domestic animals. Two important bacteria are at present in use—viz., Danysz bacillus and Neumann's bacillus, to which may perhaps be added Issatchenko's bacillus, which, however, is by no means so satisfactory, as it loses its effect when passed through several generations of rats.

Danysz bacillus, which is probably the *Bacillus typhi murium* of Löffler, was obtained in 1900 from an epidemic among harvest-mice, and is often sold as Liverpool virus, Pasteur virus, and Laroche virus; in the tropics it quickly loses its virulence.

Neumann's bacillus, obtained in 1903 from the urine of a child suffering from cystitis, and often called 'ratin,' is believed to be efficacious. The prepared virus is supplied in tins, and is distributed about the rat runs in spoonfuls wrapped in paper.

On a small scale the gas evolved from the Clayton apparatus is useful in killing rats, etc., in ships and houses. This method of destruction is described in Chapter XXXII.

Recently it has been advocated that laws should be passed making compulsory the destruction of rats by municipalities and other local authorities.

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CHAPTER XXII

BIOLOGICAL CAUSES OF DISEASE (*continued*)

Vegetal parasites—Thallophyta—Algæ—Fungi—Phycomycetes—Ascomycetes—Basidiomycetes—Hyphomycetes—References.

VEGETAL PARASITES.

The vegetal kingdom is usually divided into the following four chief groups :

I. Thallophyta, a great variety of plants whose vegetative body may consist of one or many cells forming a more or less branched thallus.

II. Muscineæ or Bryophyta, including cormophytic forms as well as forms with a leaf-like thallus.

III. Pteridophyta, or fern-plants.

IV. Phanerogams, or flowering-plants.

THALLOPHYTA.

All vegetal parasites of man belong to the Thallophyta, which consist of two classes :

Class A. The Algæ.—These possess chromatophores, while many species are provided with chlorophyl.

Class B. The Fungi.—No chromatophores and no chlorophyl.

CLASS A. THE ALGÆ.

The Algæ contain four orders :

I. Cyanophyceæ.
II. Chlorophyceæ.
III. Pheophyceæ.
IV. Florideæ.

Only the order Cyanophyceæ has importance from the point of view of human parasitology. The order contains two families :

I. Nostocaceæ, organisms containing chlorophyl.
II. Bacteriaceæ, organisms not containing chlorophyl.

The family Bacteriaceæ is very important, containing most of the pathogenic micro-organisms of man. As, however, the study of bacteria forms a special branch of science, on which numerous works and textbooks are available, we shall not deal with it, reserving ourselves to describe only the non-bacterial fungi.

CLASS B. THE FUNGI.

Fungi play a very important rôle in human, animal, and vegetal pathology; they also play an important part in some biological processes—for instance, *fermentation.*

The study of fungi is called 'mycology,' and a disease due to a fungus is termed a 'mycosis.' Thus 'otomycosis' means a mycosis of the ear; 'onychomycosis,' a mycosis of the nails; 'dermatomycosis,' a skin disease due to fungi.

The investigation of fungi began long before that of *bacteria.* In 1837 Remak discovered the parasite of *favus,* which was more completely described by Schönlein in 1839. Between 1841 and 1844 Gruber described the fungi found in thrush and ringworm.

Morphology.—Fungi are Thallophytes without chlorophyl, and do not contain starch or chromatophores. Their vegetative body, or thallus, consists generally of a mass of filaments or threads termed the 'mycelium.' The threads or filaments forming the mycelium are called 'hyphæ.' The mycelial threads or hyphæ may be *septate* or *non-septate.* Their walls do not consist of ordinary cellulose, but of a substance known as *fungus-cellulose,* which does not stain blue by iodine and sulphuric acid.

Nutrition.—The fungi, being unprovided with chlorophyl, cannot make use of the carbon dioxide of the air, and therefore derive their carbonaceous food material from complex organic compounds, as, for instance, decaying organic substances.

Mode of Life.—Fungi live as parasites or as saprophytes. They may live one way or the other, according to circumstances. Fungi are parasites of man, of the lower animals, and of plants.

Reproduction.—The seeds of the Phanerogamia may be said to be represented in the fungi by the roundish or oval-shaped bodies called 'spores.' The spores multiply by budding, producing daughter spores, identical with the parent spores. Under certain conditions the spore, by a process of germination, gives rise to a true mycelial filament, which ramifies, producing mycelial hyphæ. Some of the terminal hyphæ are shorter and structurally different from the other hyphæ, and they become organs of fructification, which produce spores. The formation of spores upon these hyphæ takes place in various modes, of which five different types may be distinguished.

1. *Conidia or Exospores.*—These are non-sexual spores, which take origin by a process of budding or septation from the extremity of a germinal mycelial hypha or *sporophora.* The spores may all be of the same size, or, at other times, some are much larger *macroconidia,* others smaller *microconidia.* The conidia are at first always unicellular, but later they may divide and become multicellular.

2. *Chlamydospores or Endoconidia.*—These are asexual globular spores of great size, and provided with a thick membrane. Chlamydospores are terminal or intramycelial.

3. *Endospores or Gonidia.*—These spores take origin inside a special spore-case structure, or *sporangium*, which is often terminal and aerial. Endospores which are free and provided with organs of locomotion (cilia or flagella) are called *zoospores*, and the sporangium is known under the name of *zoosporangium*.

Ascus Fructifications, or *Asci*, are special sporangia containing four or eight or a multiple of eight spores arranged in a single line. These spores are called *ascospores*. Each ascospore presents two membranes, *one internal*, *one external*. The external membrane frequently shows a pore, which is called the *germinating pore*.

Basidia Fructifications.—Basidia are large elongated cells, each of which supports at its apex two or four slender processes (sterigmata), each terminating in a small roundish conidium or basidio-spore.

4. *Zygospores.*—These are the product of a process of conjugation or modified sexual act between two special hyphæ. These hyphæ emit small club-shaped branches, which come into contact and fuse together, giving rise to a new large cell, which presents a very resistant double wall. The special branches (*gametes*) which come into contact and unite to produce the *zygospore* do not show any apparent sexual differentiation.

5. *Oospores.*—These are formed by a complete sexual act or fertilization, and can therefore be compared with a fertilized ovum.

The female element (*oosporangium*, *oogonium*) contains one or more roundish protoplasmatic masses (macrogametes or *oospheres*, *female gametes*), and presents a thick wall pierced by several *pores*. The male gamete (*antheridium*), which originates on a delicate special hypha, comes into contact with the oosporangium, sending a protoplasmatic process through it. In other cases the *antheridium* divides into several motile bodies called *microgametes*, *antherozoids*, or *spermatozoids*, which come into contact with the oosporangium, and fertilization takes place. In some rare cases the transformation of the oosporangium into an oospore is in reality a process of parthenogenesis.

Classification.—Fungi are divided into five orders:

I. Myxomycetes.—Higher fungi, mostly aerial; many-celled mycelium; reproduction by asexual spores.

II. Phycomycetes.—One-celled thallus, becoming septate only during sporulation; reproduction takes place by asexual and sexual spores.

III. Ascomycetes.—Reproduction by asexual spores; presence of *ascus fructifications*.

IV. Basidiomycetes.—Reproduction by asexual spores; presence of *basidia fructifications*.

V. Hyphomycetes, or Fungi Imperfecti.—Fungi of very different groups, the botanical position of which cannot be determined with certainty in the present state of our knowledge.

The fungi parasitic in man are all found practically among the Phycomycetes, the Ascomycetes, and the Hyphomycetes. Only one species of importance is found among the Basidiomycetes, and none among the Myxomycetes.

ORDER PHYCOMYCETES.

This order is divided into three suborders :

I. Chytridiæ.
II. Oomycetes (oosporaceæ).
III. Zygomycetes or Zygosporaceæ.

The Phycomycetes parasitic on man all belong to the suborder Zygomycetes.

SUBORDER ZYGOMYCETES.

These fungi reproduce sexually and asexually. The sexual reproduction takes place by formation of *zygospores*. The asexual reproduction takes place by formation of conidia, gonidia (endospores), and chlamydospores (endoconidia).

The Zygomycetes are divided into four families, among one of which only—the Mucoraceæ—are found human parasites.

FAMILY MUCORACEÆ.

These organisms have a ramified thallus, branches taking origin laterally or by dichotomy. Some species are provided with *rhizoids*, root-like hairs by which they are attached to the surface on which they grow. From the surface of the mycelium some aerial branches called 'gonidiophores' take origin, each of which supports on its distal extremity a pear-shaped, globular or claviform sporangium called *gonidangium*. The *sporangium* is at first separated from the gonidiophore by a septum, which later protrudes into the lower portion of the sporangium to form a variously-shaped structure termed the *columella*.

Inside the sporangium or gonidangium *endospores* or *gonidia* develop by free cell-formation.

The sporangium protoplasm not used in the formation of endospores gives rise to a peculiar mucilaginous substance, which at a later period, by absorption of water, causes the bursting of the sporangium. Each endospore or gonidium, when it has become free, gives rise to a mycelial tube by germination. This mycelial tube ramifies, and a new mycelium is formed.

In some species, under certain conditions a sexual reproduction may take place. This consists in the conjugation of undifferentiated non-motile gametes, which leads to the formation of zygospores.

Many species, when vegetating in unfavourable media, reproduce only by formation of conidia and chlamydospores.

Mucoraceæ are extremely common as parasites or saprophytes of plants and animals. A mycosis due to these parasites is often termed 'mucormycosis.'

Mucoraceæ can be easily grown on sugar culture media—for instance, Sabouraud's maltose agar—or even on ordinary agar. The optimum temperature for their growth is between 35° and 40° C. The Mucoraceæ require plenty of oxygen, and therefore the media tubes must never be closed with rubber caps. When there is not enough oxygen, the Mucoraceæ lose their characteristics, and give rise to oidium or yeast-like forms.

Classification.—Four genera of Mucoraceæ are found to contain species parasitic on man :

Family Mucoraceæ.
- Mycelium ramified, no rhizoids—*Mucor.*
- Mycelium non-ramified, with or without rhizoids; peduncle supporting sporangium terminates in a special formation, encircling the base of the columella —*Lichtheimia.*
- Mycelium with rhizoids; columella ovoid —*Rhizomucor.*
- Mycelium with rhizoids; columella hemispheric, shaped like a mushroom—*Rhizopus.*

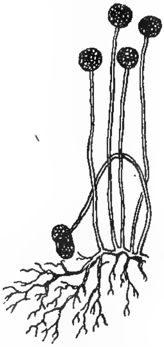
FIG. 265.—MUCOR MUCEDO.

Genus Mucor Micheli 1729.

Mucor mucedo Linnæus 1764.

Synonyms.—*Mucor vulgaris* Micheli 1729, *M. sphærocephalus* Bulliard 1791.

Hyphæ carrying sporangia (sporangiophores) are long and erect; the sporangium is globular, 100 to 200 μ in diameter; its colour brownish; its surface covered by fine, minute crystals of oxalate of calcium. The spores (gonidia) are elliptical, with a smooth surface. The columella is ovoid-shaped, and generally yellowish. Occasionally very large zygosphores may be observed.

M. mucedo L. is very common, living in organic substances in decomposition —for instance, horse-dung. It is the cause of a deadly disease in bees, but is seldom found in man.

Mucor pusillus Lindt 1886.

Mycelium at first white, then yellowish. The hyphæ carrying sporangia are much shorter than in the preceding species. The sporangium is globular, at first pale greyish, then dark greyish. Its diameter varies between 50 and 80 μ. The columella is claviform, ovoid or spherical, yellowish or brownish. The spores are smooth, spherical, 3 to 3·5 μ in diameter.

M. pusillus is often found in bread which has been soaked in water. It is very pathogenic to rabbits; it has occasionally been found in man.

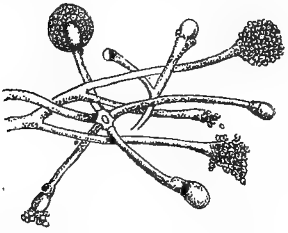
FIG. 266.—LICHTHEIMIA CORYMBIFERA VUILLEMIN. (After Lichtheim.)

Genus Lichtheimia Vuillemin 1904.

Lichtheimia corymbifera Cohn 1884.

Synonym.—*Mucor corymbifer* Cohn 1884.

Mycelium first white, then yellowish. The sporangia are pear-shaped, 10 to 70 μ in diameter; columella conical, dark greyish or brownish; spores elliptical, 2 to 3 μ. The hyphæ carrying sporangia are ramified in corymbiform formation. This parasite has been observed several times in man.

Lichtheimia ramosa Lindt 1886.

Synonym.—*Mucor ramosus* Lindt 1886.

Closely resembling *L. corymbifera*, but rhizoids are often present. The spores are larger, ovoidal, 4 to 7 μ in length. The columella is always smooth.

This species has been observed in man by Lindt. According to Vuillemin, it is frequently found in the nasal mucus of horses.

Genus **Rhizomucor** Lucet and Costantin 1900.

Rhizomucor parasiticus Lucet and Costantin 1900.

Mycelium at first greyish, later brownish. Sporangium globular, 35 to 80 μ. Hyphæ carrying sporangia are often ramified, and are between 1 and 2 centimetres in length. They are often provided at their basal portion with rhizoids.

The columella is ovoid or pyriform; dark brownish; spores ovoid; longitudinal diameter, 4 μ; transverse diameter, 2·5 μ.

R. parasiticus is pathogenic for the guinea-pig and rabbits. It has once been found in the expectoration of a woman.

Rhizomucor septatus von Bezold.

Synonym.—*Mucor septatus* von Bezold.

Rhizoids present; sporangia spherical, with a smooth, or occasionally slightly muriform, surface. Diameter about 30 to 35 μ; columella spherical, brownish; spores roundish or slightly oval, from 2·5 to 4 μ. The spores are of a yellowish colour.

This species was found by Siebenmann in a case of otomycosis.

Genus **Rhizopus** Ehrenberg 1820.

This genus contains only one species.

Rhizopus niger Ciaglinski and Hewelke 1893.

Synonym.—*Mucor niger* Ciaglinski and Hewelke 1893.

The mycelial filaments are provided with rhizoids. Sporangia globular, of black colour when ripe. Spores ovoid, smooth. Columella at first globular, but later takes a cylindrical shape, and when the spores have become detached, develops a peculiar mushroom appearance.

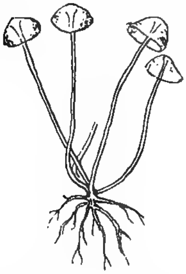

FIG. 267.—RHIZOPUS NIGER CIAG. AND HEW.
(After Ciaglinski.)

This species was discovered by Ciaglinski and Hewelke in a case of black mycosis of the tongue.

General Remarks on Mycoses due to Species of the Family Mucorinaceæ.—These mycoses are generally called mucormycoses. They have been recorded several times in man.

MUCORMYCOSIS OF THE NOSE.—Several cases are on record (Schubert, Siebenmann) in which Mucorinaceæ were found in various affections of the nose. Their pathogenic power in such affections has not been demonstrated with certainty.

MUCORMYCOSIS OF THE TONGUE.—Ciaglinski and Hewelke, and later Seniyiak, have described cases of so-called 'black tongue,' due to Mucorinaceæ of the genus *Rhizopus*.

MUCORMYCOSIS OF THE EAR—OTOMUCORMYCOSIS.—Several cases are found in the literature (Siebenmann, Böke, Huckel, etc.). Almost always *Lichtheimia corymbifera* was present. In the tropics we have observed two cases in which *L. ramosa* was present. When the fungus is in great quantity, the patient complains of tinnitus aurium and deafness—the same symptoms as those produced by a plug of cerumen in the external auditory meatus.

MUCORMYCOSIS OF THE LUNGS.—Several cases are on record. The patients generally complain of chronic cough, and the sputum may contain the fungi. Generally the mycelium only is found. Potassium iodide given in large doses produces good results.

GENERAL MUCORMYCOSIS.—One case only is on record—that of Paltauf. The patient during life presented fever, slight jaundice, enlargement of the spleen and liver, with signs of diffuse bronchitis and obscure nervous symptoms. At the post-mortem the brain presented several foci of a friable, yellowish substance; the other internal organs showed nodules of various size, some rather hard; others had undergone a purulent change. In all these formations mycelial threads were found; in the lung nodules fructifications (sporangia) were also present, which enabled him to determine the fungus as *L. corymbifera*. According to Paltauf, the infection must have originated from the intestine, which showed several ulcerative lesions containing the same fungus.

ORDER ASCOMYCETES.

These fungi are characterized by their mode of reproduction—viz., by spores originating inside special cells called *asci*. The spores (ascospores, endospores, gonidia) inside the asci are generally four or eight or a multiple of eight. While these fungi live a parasitic life no asci are found, and reproduction takes place by germination and conidia. The fungi belonging to this order are often pleiomorphic, their morphological characters changing according to the medium on which they live.

The Ascomycetes are divided into two suborders:

I. *Gymnoascees.*—Asci not enclosed in any special enveloping structure.

II. *Carpoascees.*—Asci produced in special fructifications.

SUBORDER GYMNOASCEES.

Of the Gymnoascees, only two families—the Saccharomycetes and the Gymnoasceæ—are parasitic on man.

FAMILY SACCHAROMYCETES.

These organisms are generally round or ovoid cells, presenting a cell wall of single or double contour; the internal protoplasmatic mass often shows granules and vacuoles. During active vegetation as parasites they reproduce by a *budding process*, hence the name of *budding fungi;* when living on artificial media under unfavourable nutritive conditions, or in the absence of oxygen, they may multiply by formation of endospores or ascospores.

The organisms are, as a rule, unicellular plants, but at times the cells elongate to form mycelial hyphæ—so much so that occasionally a complicated ramifying septate mycelium is produced. This occurs, for instance, when the organisms are cultivated in certain fluid culture media—for example, fluid beer-wort. In such cases side-buds, which separate into conidia-like bodies may also develop on the hyphæ.

The family Saccharomycetes contains three genera:

I. *Genus Endomyces.*—Reproduction by external spores, ascospores, and spores situated inside the mycelial tubes.

II. *Genus Saccharomyces.*—No true mycelial threads; reproduction by budding and ascospores.

III. *Genus Cryptococcus.*—Reproduction by budding only; no *ascospores;* no mycelial threads.

The fungi belonging to the genus *Saccharomyces* and *Cryptococcus* are commonly known under the name of blastomycetes (or yeasts), while the diseases due to them are termed 'blastomycoses.'

Genus Endomyces Rees 1870.

Endomyces albicans Robin 1853.

Synonyms.—*Oidium albicans* Robin 1853, *Syringospora robini* Quinquand 1868, *Saccharomyces albicans* Rees 1877, *Monilia albicans* Zopf. 1890, *Endomyces albicans* Vuillemin 1898.

This fungus was discovered by Berk and Gruby in 1842 in thrush patches.

Parasitic Life.—This fungus forms white patches on the tongue and buccal mucosa. The patches are easily detached. A particle of the patch examined under the microscope shows: Septate mycelial threads, simple or ramified, the articles of which are straight or somewhat bent. Each article or cell is about 20 μ in length, and 3 to 5 μ in breadth. At the terminal portion of each mycelial thread three or four shorter ovoid elements are found which reproduce by budding. Some similar ovoid or roundish globular refringent cells may be observed, originating laterally at the septations of the mycelium. These globular elements, which were at first considered to be spores, become detached and reproduce by germination.

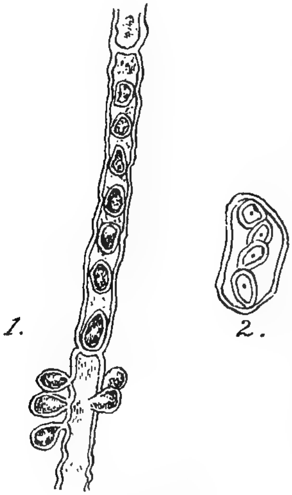

FIG. 268.—ENDOMYCES ALBICANS.

(From a culture. After Vuillemin.)

1, Mycelial threads, with endospores and conidia; 2, ascus fructification.

Saprophytic Life.—Culture Characters.—The fungus grows well on slightly acid Sabouraud's and other media; is very susceptible to alkalis; does not grow abundantly in alkaline media. Does not ferment lactose; some strains liquefy gelatine; Gram positive.

In cultures the fungus appears under two forms: 1. A filamentous form, showing the mycelial threads simple or ramified. 2. A globular form, morphologically similar to a typical yeast, and reproducing by budding. Both forms may be found in the same culture.

The fungus in cultures reproduces by—

1. Chlamydospores or external spores; large globular cells 10 to 20 μ in diameter, with thick resistant walls. The chlamydo-

spores are situated at the terminal extremity of some mycelial hyphæ, and represent modified mycelial articles.

2. Asci containing four ascospores.

3. Internal Spores.—These are oval cells with membrane, protoplasm and nucleus similar to the external spores. The internal spores are arranged in a single string inside some mycelial tubes.

Pathogenicity.—The fungus is the cause of the well-known affection termed *thrush.* It is generally localized in the oral mucosa, but in certain cases it may spread to the œsophagus, stomach, and intestine. It may be found in the lungs. Rarely it gives rise to a general infection producing a type of pseudo-tuberculosis. At times *Endomyces albicans* may show pyogenic properties.

In the tropics thrush is not rare; it is found in children and cachectic adults.

Endomyces subtilis Blanchard 1895.

Found in a pustular eruption of a child by Boyer J. d'Antin, 1881, and by Babes in a similar eruption in a woman.

Endomyces subtilis closely resembles *E. albicans*, but its filaments are much more slender.

Endomyces rhoi Castellani 1909.

Found by Castellani in several cases of tropical otomycosis. The mycelial threads are very long and septate, 3 to 4 μ in breadth; there are very numerous free roundish cells, 4 to 5 μ in diameter. It grows on various sugar and ordinary media producing a whitish membranous growth.

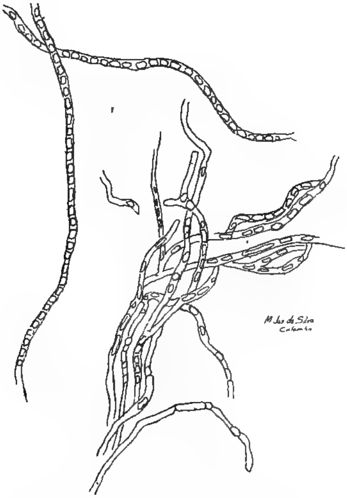

FIG. 269.—ENDOMYCES RHOI.
(From a fresh preparation. The free spores are not shown.)

Genus Saccharomyces.

No proper thallus. Reproduction by budding and endospores or ascospores.

As already stated, the fungi of this genus, as well as of the genus *Cryptococcus*, are usually called Blastomycetes, and the diseases induced by them blastomycoses.

The fungi of the genus *Saccharomyces* and *Cryptococcus* have a great importance in dermatology, as they give rise to peculiar ulcerative affections of the skin, often resembling a syphilide or a tuberculide. The first cases of blastomycosis were observed in America by Posadas, Wernike and others, who at first believed them to be a protozoal infection. Later Gilchrist, Ricketts, and others recognized the true nature of the parasites. Cases of blastomycosis are frequent in tropical countries. By some authors (Sanfelice, Roncali, etc.), cancer has been considered to be of blastomycetic origin.

Saccharomyces blanchardi Guiart 1906.

Found at an operation on a patient who had been considered to be suffering from tubercular peritonitis. The fungus had produced in the peritoneum a large whitish gelatiniform mass, weighing about 1 kilogram. The fungus grew well on all sugar media.

Saccharomyces samboni Castellani 1907.

Cells roundish—6 to 8 μ in diameter—easily grown on various media producing white colonies, which rapidly coalesce. Found by Castellani in Ceylon in a few cases of intertriginous dermatitis of the cruro-scrotal region. A similar or identical organism has been observed by Whitfield in England in a case of the same dermatitis.

Saccharomyces anginæ Vuillemin 1901.

Found by Achalme and Troisier in a case of tonsillitis showing white patches.

Saccharomyces tumefaciens Busse 1897.

Found by Busse in a benign tumour.

Saccharomyces ranulatus Vuillemin and Legrain 1900.

Observed by Vuillemin and Legrain in a tumour of the submaxillary bone.

Saccharomyces ellipsoides Rhees 1870.

Found by Maggiora and Gradenigo in a case of chronic otitis media.

Saccharomyces roseus Maggiora and Gradenigo 1890.

Found by Maggiora and Gradenigo in the Eustachian tube.

Genus Cryptococcus Kützing.

Reproduction by budding only; ascospores unknown; no fermentation of sugar media (glucose and saccharose).

Cryptococcus gilchristi Vuillemin.

Synonym.—*Oidium* (sp. ?) Gilchrist and Stokes 1896.

Found by Gilchrist and Stokes in a case of chronic ulcerative dermatitis, and later in a case which had been diagnosed as a tuberculide of the skin. After Gilchrist and Stokes's cases, other cases of blastomycosis due to an identical or similar organism have been described by Hyde, Oppenheim, Ricketts, etc. Ricketts considered these fungi to be species of *Oidium* (Endomyces), and proposed the name 'oidiomycosis' to indicate the disease produced by them.

C. gilchristi in the affected tissues has the appearance of a typical yeast—large, globular cells, reproducing by budding. In cultures, besides these globular elements, thread-like mycelial tubes may be found, presenting lateral or terminal conidia; ascospores absent. The fungus does not ferment glucose or saccharose.

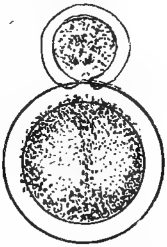

FIG. 270.—CRYPTOCOCCUS GILCHRISTI VUILLEMIN.

(After Gilchrist.)

Cryptococcus hominis Vuillemin.

Synonym.—*Saccharomyces* (sp. ?) Busse 1894.

Found in abscesses in a woman by Busse. In the pus the fungus presented itself under the shape of oval bodies, with a membrane having a double contour. These elements were arranged in groups, each group being surrounded by a special capsule. Culturally the fungus showed only roundish budding forms, no mycelium, no asci.

Cryptococcus linguæ-pilosæ Lucet 1901.

Synonym.—*Saccharomyces linguæ-pilosæ* Lucet 1901.

Found by Lucet and others in a case of so-called 'black tongue.' This affection is in other cases due to *Rhizopus niger*, and in others to *Oospora lingualis*.

Cryptococcus plimmeri Costantin 1901.

A *Cryptococcus* found by Plimmer in many cases of cancer. It is probably only a saprophyte.

Cryptococcus degenerans Roncali 1896.

Found by Roncali and others in malignant tumours: sarcomata and carcinomata.

FAMILY GYMNOASCEÆ.

Spherical perithecium, the walls of which are formed by mycelial filaments. At the extremities of these mycelial threads ascus fructifications are found. Besides vegetating under this type, the Gymnoasceæ can also vegetate under a filamentous or conidial form without any formation of asci. It is under this second form that most of the Gymnoasceæ parasitic on man vegetate.

The genera *Microsporon*, *Trichophyton*, *Achorion* are at the present time considered to belong to the family Gymnoascees on account of the following facts:

1. These three genera, as demonstrated by Matruchot and Dassonville, have the greatest resemblance to the filamentous type of some typical Gymnoascees.

2. A species of Gymnoascees, *Ctenomyces serratus*, when living saprophytic, shows perithecia and ascus fructifications; when inoculated into animals, vegetates under a filamentous form very similar to a *Trichophyton*, and gives rise to a Trichophyton eruption.

The genera of Gymnoascees containing human parasitic species are the following: (1) *Microsporon*; (2) *Trichophyton*; (3) *Epidermophyton*; (4) *Endodermophyton*; (5) *Achorion*; (6) *Oospora*; (7) *Montoyella.*

Genus Microsporon Gruby 1843.

Mostly parasitic in the hairs; mycelial spores are roundish, small (2 to 3 μ), and irregularly arranged in a mosaic-like way. Cultivation fairly easy; reproduction by chlamydospores, conidia, and septated and unseptated spindles.

Microsporon audouini Gruby 1843.

This parasite was described by Gruby in 1843, but his investigation was forgotten, till Sabouraud, in his classical researches on ringworm in 1892, demonstrated the plurality of the species of the fungi found in this affection, and showed that a form of tinea capitis was due to the microsporon described by Gruby.

Parasitic Life.—Around the affected hairs the fungus forms by means of its mycelial spores a white opaque sheath, extending 2 or 3 millimetres above the opening of the follicle to the hair bulb. The sheath is composed of a mosaic of small, roundish, or polyhedral spores, the diameter of which varies between 2 and 3 μ. In the interior of the hair a few mycelial filaments of the fungus may be observed. The fungus very seldom attacks glabrous parts of the body.

Saprophytic Life.—Cultures.—*Microsporon audouini* grows well on Sabouraud's maltose agar and other media. The rate of growing is very slow. In maltose agar the growth becomes evident about a week after inoculation under the appearance of a plaque, beneath the surface, of a so-called 'satiny aspect.' In a few days more aerial hyphæ develop, extending above the surface. When the development is complete—generally this takes about six to eight weeks—the growth is roundish, and presents often a central knob, and some concentric rings of a whitish, greyish colour. The cultural characters, however, are variable; pleiomorphism is of common occurrence. The cultural characters have been thoroughly investigated by Sabouraud, Fox and Blaxal, Bodin, and others. The fungus very slowly liquefies gelatine; on potatoes it produces a brownish discoloration, compared by Sabouraud to the colour of dried blood.

Reproduction.—This takes place—

1. By sprouts from the mycelial tubes.
2. By small terminal and lateral conidia.
3. By large unilocular or multilocular spindle conidia. These spindles are large structures 30 to 60 μ in length, and 15 to 18 μ in breadth. They may be septated or non-septated.
4. By formation of chlamydospores.

Pathogenesis.—*Microsporon audouini* causes the most obstinate form of tinea capitis. The patches affected are often large, scaly, and present stumps, provided with an opaque whitish sheath. It seldom attacks glabrous parts of the body. *M. audouini* is extremely common in England; rare in the South of Europe (Italy); extremely rare in the tropics. We have never seen cases of ring-worm due to *M. audouini* in Equatorial Africa or Ceylon, but a few cases have been described in Brazil and Madagascar.

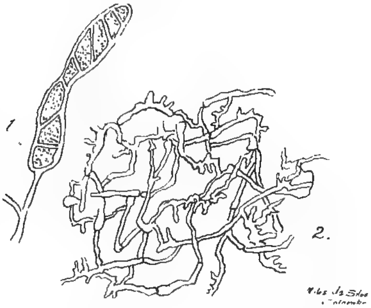

FIG. 271.—MICROSPORON. (From cultures.)
1, Septated spindle body; 2, mycelium.

Varieties of Microsporon audouini.—*M. audouini* seems to live only on the human subject, but closely allied varieties have been found by Fox in cats, by Bodin in dogs, by Bodin, Fox, and others in horses. These varieties may affect man. Bodin and other authors have described two of these varieties as different species under the name of *Microsporon equinum* Bodin and *M. caninum* Bodin, seu *M. lanosum* Sabouraud.

Genus Trichophyton Malmsten 1848.

In contrast to the genus *Microsporon*, the mycelial spores are large (4 to 7 μ). Hairy and non-hairy parts of the body may be attacked. In cultures the conidia are roundish, and often supported by short sterigmata.

General Considerations.—During their parasitic life the species of the genus *Trichophyton* vegetate according to two types: (1) Mycelial filaments; (2) mycelial spores.

The mycelial filaments consist of long cylindrical cells, separated by septa. The so-called mycelial spores are simply a modification of the mycelial filaments, due to the septa being much closer, so that the cells limited by them are almost as broad as they are long. The term 'mycelial spores' is incorrect, as they are not organs of reproduction, but only vegetative organs.

When the shape of these mycelial spores or sporulating mycelia is roundish or oval, the filament takes a moniliform appearance.

Moreover, these cells are easily dissociated. Such type is called 'fragile mycelium.' To this type belongs, for instance, *Trichophyton sabouraudi* R. Blanchard.

When the mycelial spores are square, the filament straight, and its articles long, the mycelium is called 'resistant.' This type is observed, for example, in *Trichophyton tonsurans* Malmsten.

Cultivation.—Most *Trichophytons* can be cultivated, some cannot. The best medium is Sabouraud's maltose agar, the composition of which is the following:

Maltose	4 grammes.
Peptone Chassaing	1 gramme.
Agar	1·50 grammes.
Distilled water	100 c.c.

On this medium, however, pleiomorphism is of frequent occurrence, and therefore, for comparative studies, cultures on ordinary agar media are to be preferred.

Reproduction.—The reproduction takes place by—

1. Lateral and terminal conidia, often suported by short sterigmata.
2. Chlamydospores.
3. Large terminal septated and unseptated spindles.

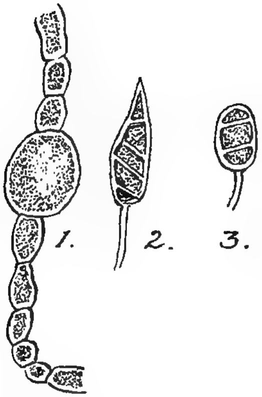

FIG. 272.—TRICHOPHYTON. (Preparation from cultures. After Bodin.)

1, Chlamydospore; 2 and 3, septated spindle bodies.

Classification. — *Trichophytons* can be divided into the following groups:

I. ENDOTHRIX.—The fungus develops in the interior of the hair; does not cause suppuration; of human origin only.

The species of *Trichophytons* of the type Endothrix are *Trichophyton tonsurans*, *T. sabouraudi*, *T. violaceum*, *T. foxi*.

II. ECTOTHRIX AND ENDO-ECTOTHRIX.—The fungus is present only on the surface of the hair, or both on the surface and in the interior; often pyogenic; of animal origin.

The species of the group Ectothrix and Endo-Ectothrix are: *T. mentagrophytes*, *T. depilans*, *T. equinum*, *T. felineum*, *T. megnini*, *T. verrucosum*, *T. ochraceum*, *T. album*.

III. TROPICAL TRICHOPHYTONS.—The fungi do not attack the hair or hair-follicles; do not cause suppuration.

The species constituting the third group are: *T. albiscicans*, *T. blanchardi*, *T. ceylonense*, *T. macfadieni*. It is to be noted that in the tropics also *Trichophytons* of the Endothrix and Ecto- and Endo-ectothrix type are often found.

Trichophyton tonsurans Malmsten 1845.

Synonyms.—*Trichomyces tonsurans* Malmsten 1845, *Oidium tonsurans* Zopf 1890, *T. megalosporum endothrix* Sabouraud 1894, *T. crateriforme* Bodin 1902.

Causes the so-called '*black-dotted*' ringworm; somewhat rare in England; very common in hot climates; type Endothrix. The mycelial cells are large (4 to 5 μ), quadrangular (so-called resistant mycelium type). Grows well on maltose agar and other media; on maltose agar colonies are white or yellowish, often crateriform, and present a velvety surface at first, later powdery. In hanging-drop cultivations spore-bearing fructifications can be seen.

T. tonsurans, besides producing a type of tinea capitis, produces, also, a form of tinea corporis.

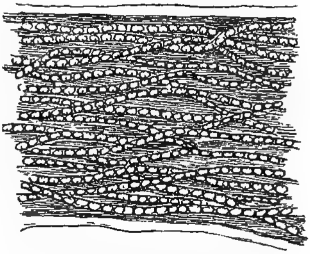

FIG. 273.—TRICHOPHYTON TONSURANS MALMSTEN. (Preparation of a hair in liquor potassæ. After Sabouraud.)

Trichophyton sabouraudi R. Blanchard 1895.

Synonym.—*Trichophyton acuminatum* Bodin 1902.

This is of the type Endothrix. Mycelial threads have a moniliform appearance, and their articles become easily dissociated (so-called fragile mycelium). Grows well on maltose agar, giving rise to conical white colonies; often acuminate with central plumes, and occasionally may present yellowish or pinkish rings. In hanging-drop cultures aerial filaments with lateral spores are seen.

T. sabouraudi causes a form of tinea capitis called by Sabouraud 'tondante peladoide.' It may cause also a variety of tinea circinata.

Trichophyton violaceum Bodin 1902.

Discovered by Sabouraud in a case of tinea barbæ; belongs to the type Endothrix. The colonies on maltose agar are at first of a light brownish colour, and become violet later on. This species is common in Italy. It is occasionally found in the tropics.

Trichophyton flavum Fox 1908.

Described by Colcott Fox in some cases of tinea capitis, Endothrix type. Grows easily on various sugar media, its colonies being characterized by a central reddish nodule, which later becomes crateriform assuming a speckled appearance. The rest of the culture has a delicate but distinct primrose colour.

Trichophyton mentagrophytes Robin 1853.

Synonyms.—*Microsporon mentagrophytes* Robin 1853, *Sporotrichum mentagrophytes* Saccardo 1886.

Endo-ectothrix, mycelial spores being mostly situated outside the cuticle of the hair, while a few are found in the interior. The spores are of very unequal size (2 to 11 μ). On maltose agar very large colonies, of a white colour, appear with surface often presenting radial furrows. This *Trichophyton* is of animal origin (horses, cows, dogs, and perhaps pigs and sheep); it is pyogenic in man, giving rise to a form of trichophytic sycosis, and also to a variety of tinea corporis with suppurative foci.

Trichophyton depilans Mégnin 1879.

Synonym.—*T. flavum* Bodin 1902.

Endo-ectothrix; mycelial spores oval (5 to 11 μ); colonies on maltose agar of a yellowish colour; is parasitic in the horse and the calf; may occasionally infect man, giving rise to a variety of tinea barbæ. In contrast to *T. mentagrophytes*, this *Trichophyton* is not pyogenic.

Trichophyton equinum Gedoelst 1902.

Endo-ectothrix; mycelial spores oval, 4 to 6 μ in length; on maltose agar white orbicular colonies appear; and later the portion of the colony which is in contact with the medium becomes yellowish, and afterwards dark red. This *Trichophyton* is parasitic of the horse, and may attack man; is not pyogenic.

Trichophyton felineum R. Blanchard 1895.

Ectothrix; fragile mycelium; parasitic on cats, and also on dogs, horses, calves; may infect man, giving rise to a variety of tinea capitis or to a peculiar form of tinea corporis, described by Sabouraud under the name of 'circinate dysidriform trichophytosis.'

Trichophyton megnini R. Blanchard 1895.

Synonym.—*T. roseum* Bodin 1902, *T. rosaceum* Bodin 1902.

Endo-ectothrix; the mycelial spores found in the interior of the hairs are very large—8 to 9 μ in diameter; colonies on maltose agar at first white, later pinkish or of a deep rose colour; parasitic in fowls and pigeons; may infect man, causing a variety of tinea barbæ.

Trichophyton verrucosum Bodin 1895.

Endo-ectothrix. Though this fungus produces typical trichophytic lesions, its cultural characters are somewhat similar to those of an *Achorion*—grey acuminate cultures with irregular verrucose surface. It is found parasitic on the donkey. The same or similar species are found parasitic on the horse and on some birds. All these so-called faviform *Trichophytons* may occasionally infect man.

Trichophyton ochraceum Sabouraud 1907.

Type Ectothrix, of animal origin; cultures somewhat similar to favus. On maltose agar the colonies are characterized by a yellow ochre knob. On ordinary agar the surface of the colonies is cerebriform. Optimum temperature, 25° C. It is easily inoculated in guinea-pigs.

Trichophyton album Sabouraud 1907.

The cultures are extremely like favus, but are generally more deeply umbellicated and more regularly folded. Optimum temperature, 25° C. Can be inoculated in guinea-pigs.

Trichophyton albiscicans Nieuwenhuis 1907.

Found in tinea albigena. In preparations from scrapings the spores are very rare (4 to 5 μ in diameter). Growth on maltose agar very slow; colonies whitish, with a powdery surface.

Trichophyton macfadyeni Castellani 1905.

Synonym.—*Microsporon macfadyeni* 1905.

Found in tinea alba; mycelial threads slender (2 to 3 μ in breadth); spores oval, 3 to 3·5 μ maximum diameter. Grows with great difficulty.

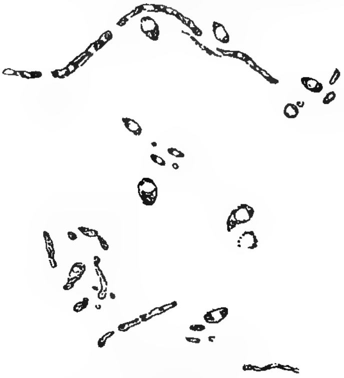

FIG. 274.—TRYCHOPHYTON MACFADYENI. (Stained with fuchsin.)

Trichophyton blanchardi Castellani 1908.

Synonym.—*T. sabouraudi* Castellani 1905.

Found in a form of tropical trichophytosis, described by Sabouraud. Mycelial tubes do not show a double contour, are often bent; spores roundish, of various size; cannot be grown.

Trichophyton ceylonense Castellani 1908.

Found in tinea nigrocircinata; spores rare, roundish, 4 to 5 μ in diameter; mycelium regular, with a double contour. The fungus cannot be grown.

Genus Epidermophyton Sabouraud 1907.

The fungi of this genus grow superficially on the human skin without invading the hair follicles; do not produce suppuration. The cultures often undergo rapid degenerative changes. Three species: *E. cruris*, *E. perneti*, *E. rubrum*.

Epidermophyton cruris Castellani 1905.

Synonyms.—*Epidermophyton inguinalis* Sabouraud 1907, *T. castellanii* Brook 1908, *T. cruris* Castellani 1905.

Found in most cases of tinea cruris, or dhobie itch; does not invade the hair follicles. In scrapings from the affected regions the mycelial tubes are generally straight, and often show a double contour. In old cases banana-shaped form and other degenerative forms are present. The fungus grows on maltose agar very slowly; colonies orbicular-shaped or acuminate, of a greyish-yellow colour; later they become greenish white. The fungus has no pyogenic properties.

Epidermophyton perneti Castellani 1907.

Synonyms.—*T. perneti* Castellani 1907.

Found in some cases of tinea cruris; very similar to *T. cruris;* the growth, however, is much more rapid, and the cultures present a delicate pinkish colour, which is lost in subcultures.

Epidermophyton rubrum Castellani 1909.

Found in some cases of dhobie itch. On Sabouraud and glucose agars the growth is of a deep red colour; not lost in subcultures.

Genus Endodermophyton Castellani 1909.

The fungi belonging to this genus are characterized by their growing between the superficial and deep strata of the epidermis forming an interlacing felt of mycelia, which detaches the horny and granular layers from the rete Malpighi. Do not invade the hair follicles; do not cause suppuration. So far have not been cultivated.

Endodermophyton concentricum Blanchard 1901.

Synonyms.—*T. mansoni* Castellani 1905, *Aspergillus tokelaui* Wehmer 1907.

Causes tinea imbricata. Fungus very abundant in the scales; mycelial articles straight, regular, 3 to 4 μ in breadth, spores rather large (4 to 5 μ), roundish or oval. According to Nieuwenhuis, the fungus can be cultivated, and gives rise to crateriform, dark-coloured colonies. We have been unable to confirm Nieuwenhuis's results as regards cultivation.

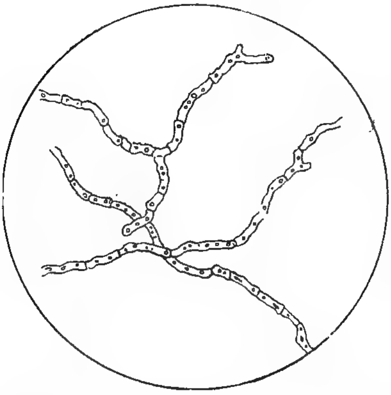

FIG. 275.—ENDODERMOPHYTON FOUND IN TINEA INTERSECTA.

Endodermophyton castellanii Perry 1907.

Causes a tropical dermatomycosis called tinea intersecta. In the scales the mycelium is fairly abundant, but free spores are extremely rare or absent; mycelial threads are straight, and have a double contour; breadth 3 to $3\frac{1}{2}$ μ; mycelium may ramify; attempts at cultivation have so far failed.

Genus Achorion Lebert 1845.

During parasitic life the mycelial segments are much longer than in the genera *Trichophyton* and *Microsporon*, and form the well-known sulphur-coloured *scutula*. In cultures on solid media, often disc-like colonies somewhat resembling scutula arise; gelatine is liquefied fairly rapidly.

Achorion schœnleini Lebert 1845.

Synonyms.—*Oidium schœnleini* Lebert 1845, *O. porriginis* Montague, *Oospora porriginis* Saccardo 1886.

Causes the well-known affection called *favus*, which is characterized by the presence of peculiar disc-shaped crusts called *scutula*, of a yellow colour, and emitting an offensive odour compared to the smell of mice's urine.

The fungus may infect the hairs or glabrous parts of the body; it may attack the nails. In the hairs the mycelium is very abundant, the segments being comparatively long.

Sometimes the mycelial threads divide into three or four branches, each of which terminates in a single row of roundish spores. This is known as *favic tarsus*.

Cultures.—*Achorion schœnleini* grows very slowly on maltose agar. The colonies are at first whitish and roundish, later may become brownish, and, apart from the colour, closely resemble the scutula. Gelatine is liquefied in between three to four days, while the *Trichophytons* take fifteen to twenty days.

Reproduction.—This takes place—

1. By endoconidia and external lateral conidia.
2. By sprouting.
3. By elongated fusiform structures analogous to the so-called 'spindles' of the *Trichophytons* and *Microsporons*, only slenderer and not septate. These formations are called by the French authors *chandeliers faviques*, on account of their shape somewhat resembling a candlestick.
4. By so-called 'favus claviform bodies' or 'yellow bodies,' which are claviform structures 8 to 15 μ in diameter, showing a double contour, and containing a granular substance. These structures should probably be considered to be chlamydospores.

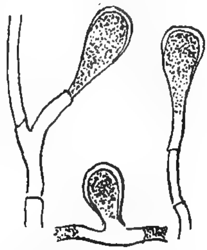

FIG. 276.—SO-CALLED YELLOW BODIES IN CULTURES OF ACHORION SCHŒNLEINI LEBERT.

(After Bodin.)

Sabouraud admits only one species of *Achorion*, other authors several. Neebe and Unna have described as many as nine: *Achorion cysticum, A. tarsiferon, A. moniliforme, A. demergens, A. akromegalicum, A. dikroon, A. radians, A. euthythrix, A. atacton.*

In the lower animals—mouse and cat—very similar species to *A. schœnleini* have been found. The variety found in the mouse has been described by Zopf 1890 under the name of *A. quinkenaum*, and may infect man, as observed by Bodin, Admason, and others. It grows readily on maltose agar producing white downy colonies.

In the dog and in fowls diseases closely resembling human favus are observed, but they are due to fungi not belonging to the genus *Achorion*. The favus of dogs is due to a fungus of the genus *Oospora*—*O. canina* Costantin and Sabrazès 1893; the favus of fowls is caused by a *Lophophyton*—*L. gallinæ* Mégnin 1881.

Achorion gypseum Bodin 1907.

Described by Bodin in 1907 in a few cases of favus. This fungus shows transition characters between the genus *Achorion* and the genus *Microsporon*. In cultures it presents all the principal characters of a microsporon, but causes in man classical favus lesions. It is easily inoculated in guinea-pigs and mice, in which it produces typical scutula.

Genus Oospora.

Mycelium very slender; some mycelial threads abstrict at their extremities chains of spores.

Oospora tozenri Nicolle and Pinoy 1908.

Causes a variety of black mycetoma in Algeria and Tunis. Masses of the fungus give rise to small, hard black grains. During parasitic life the mycelium is septate, ramified, 1 to 4 μ in breadth; chlamydospores present. On maltose agar the fungus grows best at 35° C., giving rise to whitish colonies, while the medium becomes black. Structures similar to the so-called ‘favus claviform bodies’ have been observed; some hyphæ consist of strings of small cylindrical elements 4 μ in length and 2 μ in breadth.

Oospora canina Costantin-Sabrazès 1893.

Causes the favus of dogs; may be transmitted to man, but seldom gives rise to typical favus lesions. Only mode of reproduction so far known is by chains of conidia.

Oospora lingualis Guéguen 1909.

Thin mycelial tubes, articles of which are easily dissociated. In cultures chlamydospores are present and structures resembling the claviform bodies of achorion observed in cases of *Lingua pilosa*.

Genus Montoyella Castellani 1907.

Two kinds of mycelial threads: some slender, ramified, septate; others much thicker, having numerous intermediate chlamydospores. From the thicker filaments delicate hyphæ take origin which terminate into large pear-shaped or globular conidia.

Montoyella nigra Castellani 1907.

Colonies on maltose agar black. If glycerine agar is used, the medium takes a black colour. This species, discovered by Montoya, is common in black pinta.

Montoyella bodini Castellani 1907.

Found by Bodin in a case of red pinta ; colonies whitish or greyish.

SUBORDER CARPOASCEES.

This suborder of Ascomycetes is characterized by the fact that the *asci* are not free, and do not spring directly from the mycelium. They are produced in special fructifications.

Of the suborder Carpoascees, only two families, the *Perisporiaceæ* and the *Pyrěnomycetes*, contain species parasitic on man.

Family Perisporiaceæ.

The ascagenous hyphæ are enclosed by a compact envelope of interwoven, sterile filaments. On the rupture or disintegration of this envelope (perithecium) the ascospores become free. In many cases reproduction takes place also by means of conidia.

Table showing Perisporiaceæ Parasitic in Man.

Family.	Genus.	Species.
Perisporiaceæ	Penicillium	P. crustaceum.
		P. minimum.
		P. barbæ.
		P. bouffardi.
		P. montoyai.
		P. pruriosum.
	Aspergillus	A. fumigatus.
		A. bronchialis.
		A. glaucus.
		A. nigrescens.
		A. repens.
		A. malignus.
		A. flavus.
		A. nidulans.
		A. niger.
		A. pictor.
		A. barbæ.
		A. bouffardi.
		A. fontoynonti.

Genus Penicillium Link 1809.

The whole fruit-bearing hypha with its sterigmata and conidia resembles a hair-pencil, hence the name of the genus (*Penicillium* = hair-pencil). The conidiophore hypha shows verticillate branches, which give rise to slender fusiform formations (sterigmata) abstricting chains of conidia.

Penicillium crustaceum Link. 1763.

Synonyms.—*Mucor crustaceus albus* Link. 1763, *Monilia digitata* Persoon, *Penicillium glaucum* Link. 1809, *P expansum* Link.

An extremely common saprophyte found on bread, cheese, fruits, and various organic substances in a state of decomposition.

The conidia are spherical or slightly elliptical; maximum diameter 4 μ. This fungus grows well at any temperature between 2° C. and 35° C., and is very resistant. It has been found in man by Maggiora and Gradenigo in two cases of otitis media. Heinhorn has observed it in the vomiting of four cases of acid dyspepsia.

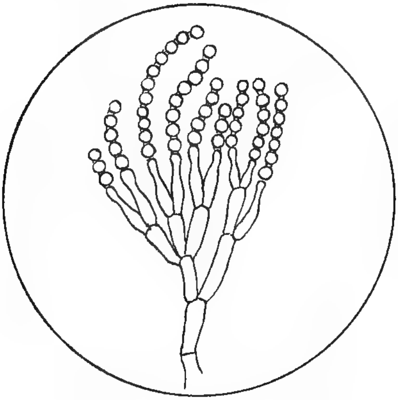

FIG. 277.—PENICILLIUM FRUCTIFICATION.

Wertheim has observed that the intravenous inoculation of *P. crustaceum* is pathogenic to rabbits, dogs, and lambs.

Penicillium minimum Siebenmann 1889.

Found in a case of acute otitis by Siebenmann. Conidia are brownish-black, smaller than in *P. crustaceum.*

Penicillium montoyai Castellani 1907.

Conidia roundish or slightly oval, smooth, 3 to 4½ μ in diameter. Grows well on maltose agar and ordinary agar; cultures of dark greyish colour. Discovered by Montoya in cases of pinta, of the greyish-violet variety. Similar species, not yet well defined, are found in other varieties of pinta.

Penicillium barbæ Castellani 1907.

Found by us growing on the hairs of the beard of natives of Equatorial Africa and in natives of Ceylon.

Penicillium pruriosum Salisbury.

Doubtful species found by Salisbury in the vaginal mucus of a woman suffering from intense vaginal pruritus.

Penicillium bouffardi Brumpt 1906.

Found by Bouffard in a mycetoma with red granules; grows well on sugar media, giving rise to red colonies.

Genus Aspergillus Micheli 1725.

The conidiophore hyphæ are not ramified, and terminate into ovoid or roundish formations, which support numerous claviform elements (*sterigmata*), each of which gives rise to a chain of roundish conidia.

Aspergilli are generally saprophytes, but they may become parasites. They are easily grown on acid media, liquid or solid, and also on alkaline media. When growing as parasites in animal tissues, they very often lose their typical morphological characters, and appear as yeast-like, oidium-like, and actinomycotic-like forms.

Aspergillus fumigatus Fresenius 1775.

The commonest *Aspergillus*, very often found on various cereals straw, hay, etc. On solid media it produces a brownish or greenish-brown, culture. The mycelial filaments are more or less ramified, the breadth varying between 2 and 3 μ. The conidiophore hyphæ are much thicker than the mycelial tubes, being about 5 μ in breadth. The sterigmata are 6 μ long; the conidia are roundish, 2·5 to 3 μ in diameter.

This *Aspergillus* is the species most frequently found in man, giving rise to an aspergillosis of various organs. The spores are very resistant. Perchloride of mercury is the antiseptic which has the greatest destructive action on these spores.

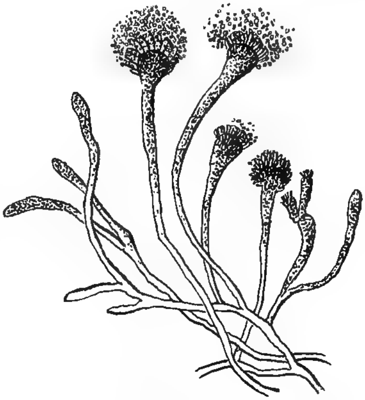

FIG. 278.—ASPERGILLUS FUMIGATUS.

Aspergillus niger von Tieghem 1867.

Synonyms.—*Sterigmatocystis antacustica* Cramer 1869, *Eurotium nigrum* De Bary 1870, *Monilia pulla* Persoon, *Aspergillus nigricans* Wreden 1874.

Erected conidiophores; hyphæ more than 1 millimetre in length. Conidia globular, 315 to 415 μ in diameter, provided with a membrane of a brownish-violet colour. Commonly found in decaying organic substances. It was first observed in man by Cramer, who observed it in the ear of a deaf patient. Later it was observed by Furbringer and others in mycotic affections of the lungs.

Aspergillus barbæ Castellani 1907.

Found by us in natives of Uganda, and in natives of Ceylon. Conidia spherical, 4 to 5 μ, of a brownish colour.

Aspergillus fontoynonti Guéguen 1909.

Found in cases of juxta-articular nodes by Fontoynont and Carougean. Small size, 150 to 200 μ; conidiophores, 14 to 18 μ in diameter; conidia oval, 3 to 5 by 4 to 6 μ.

Aspergillus nigrescens Robin.

Doubtful species, which, according to Wienfeld, causes a faviform eruption.

Aspergillus flavus De Bary 1870.

Synonyms.—*Monilia aurea* Gmelin 1791, *Eurotium flavum* De Bary 1870, *Aspergillus flavescens* Wreden 1874.

Conidiophore hyphæ terminate in a roundish formation of a gold-yellow colour. The conidia are dark yellow, roundish, 5 to 7 μ in diameter, with a surface showing numerous small mammillar prominences. Found by several authors (Wreden, Siebenmann, etc.) in the ear.

Aspergillus bronchialis Blumentritt 1901.

Mycelium of a white colour, much ramified; conidiophore hyphæ are 6·2 to 12·6 μ. Conidia roundish, with a smooth surface, of a greyish-greenish colour. This *Aspergillus* was found by Chiari in the bronchi of a patient who had died of diabetes. It has not yet been found as a saprophyte.

Aspergillus malignus Lindt 1889.

Doubtful species found in the ear by Lindt, according to whom it was very pathogenic for rabbits.

Aspergillus repens De Bary 1870.

Synonym.—*Eurotium repens* De Bary 1870.

Mycelium of a yellowish-green colour. Conidia large—7 to 8·5 μ. Found by Siebenmann in the ear three times. Its pathogenic rôle is doubtful.

Aspergillus nidulans Eidam 1883.

Synonym.—*Sterigmatocystis nidulans* Eidam 1883.

Mycelium of a greenish colour. Conidiophores are erect, 0·5 to 0·8 millimetres in length. Presence of primary sterigmata supporting secondary sterigmata, each of which gives rise to a chain of conidia. Conidia small (3 μ in diameter), globular, of a greenish colour. This species is found living saprophytic in certain nests, hence the name *A. nidulans.* In man it has been found in several cases of otomycosis; Nicolle has found it, or a very similar species, in a case of mycetoma with white granules.

Aspergillus pictor R. Blanchard 1895.

Synonym.—*Trichophyton pictor* R. Blanchard 1895.

The term *Aspergillus* (*Trichophyton*) *pictor,* introduced by Blanchard in 1895, before the plurality of species of the fungi found in pinta was demonstrated, is now used to denote the species of *Aspergillus* which is found in the pure violet variety of pinta.

This fungus shows the typical morphological characters of the genus *Aspergillus*. It grows easily in various sugar media. On maltose agar the growth has at first a whitish colour, which afterwards changes into greenish, to become violet or greenish with a violet tinge in a later period. The colour of the growth may vary according to the medium on which cultivation takes place. The conidiophores are comparatively thick; the conidia are globular, with a smooth surface.

Several other species of aspergillar and aspergillar-like fungi are found in pinta, but their botanical position has not yet been defined with certainty.

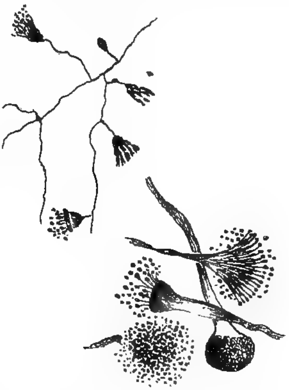

FIG. 279.—ASPERGILLUS FOUND IN PINTA.
(After Montoya y Florez.)

Aspergillus bouffardi Brumpt 1905.

Found by Bouffard in a case of black mycetoma and completely described by Brumpt. Mycelium whitish in some zones, dark brownish in others. Conidiophores erect, white, terminated in a claviform structure, bearing some short chains of roundish conidia. Chlamydospores present, 5 to 10 μ in diameter. Attempts at cultivation did not succeed.

Remarks on Aspergillomycoses.—These affections are common in man and the lower animals.

1. ASPERGILLOSIS OF THE LUNGS; ASPERGILLAR PSEUDO-TUBERCULOSIS; PNEUMOMYCOSIS OF ASPERGILLAR ORIGIN.—Aspergilli develop sometimes in the mucosa of the trachea, of bronchi, and even in the pulmonary alveoli, without giving rise to any pathogenic effect. In other cases the fungi induce pseudo-membranous and ulcerative lesions. A very serious affection is a form of pseudo-tuberculosis (*pseudo-tuberculosis aspergillina*) characterized by the presence of mycotic nodules in the lungs, liver, kidneys, and other organs. This affection, due to *A. fumigatus*, is very common in some parts of France among *pigeon-breeders* (*gaveurs de pigeons*). The same affection attacks the pigeons. The infection is probably caused by spores of *A. fumigatus* being present in the grains used for feeding the pigeons.

2. ASPERGILLOSIS OF THE EYE.—*A. fumigatus* has been found several times in ulcers of the cornea (keratomycosis aspergillina).

3. ASPERGILLOSIS OF THE EAR (OTOMYCOSIS ASPERGILLINA).—Various species of *Aspergillus* have been found in the ear. In some cases they may give rise to a serious otitis, deafness, and tinnitus. Aspergillosis of the ear is not rare in the tropics. Syringing with hydrogen peroxide two parts and alcohol one part is useful.

4. ASPERGILLOSIS OF THE NOSE.—*A. glaucus* and *A. fumigatus* have been found in the nasal cavities; the first apparently does not cause any disturbance. The second causes various inflammatory symptoms.

5. ASPERGILLOSIS OF WOUNDS AND ULCERS.—In wounds not properly treated, and in old ulcers, *Aspergilli* have been occasionally found.

6. ASPERGILLOSIS OF THE URETHRA.—In several cases a black urethral discharge has been observed, due to *A. niger.*

7. ASPERGILLOSIS OF THE SKIN.—Montoya's investigation has shown that several varieties of pinta are due to fungi of the genus *Aspergillus.* Another important tropical skin disease, Tinea imbricata, is, according to some observers (Tribondeau, Wehmer), due to an *Aspergillus*—*A. tokelau* Wehmer 1903. In our experience the fungus of *T. imbricata* never shows aspergillar fructifications, and cannot be considered to be an aspergillus.

Aspergilli may also cause some varieties of mycetoma

FAMILY PYRENOMYCETES.

Ascomycetous fungi in which the asci are contained in a perithecium presenting an orifice at the apex for the escape of the spores. According to some authors, species of this family have been found parasitic in man. This is very doubtful, though Schubert states that he found in the nasal mucus of a patient an organism closely allied to *Botrytis bassiana,* which latter species, as is well known, causes the disease of silkworm called muscardin.

ORDER BASIDIOMYCETES.

Basidiomycetes have a septate mycelium, and are devoid of sexual reproduction. They reproduce by formation of basidia. Other accessory fructifications may be present—as, for example, chlamydospores. The basidia are of two principal types: (1) autobasidia; (2) protobasidia.

The autobasidia are large, unseptated cells, giving rise at their apices to four delicate sterigmata, each of which bears a spore.

The protobasidia are septated, and appear in two chief forms:

A. Septated into four cells, each giving rise to a spore from a lateral inserted sterigma.

B. Septated by walls intersecting at right angles, each cell ending in an elongated tubular sterigma.

Of the Basidiomycetes, one species (*Ustilago hypodytes*) of the family Ustilagineæ is of special importance, while two others (*U. carbo* and *Tilletia levis*) may produce otomycosis.

Ustilago hypodytes Schlecht.

The mycelium penetrates the stem and leaves of *Arundo donax* in some parts of Provence. After a time the mycelium produces innumerable so-called brand spores by a process of division of its profusely branched hyphæ. In this way the mycelium is transformed into a brown dark mass of spores.

These brand spores, as regards the mode of their formation, may be considered chlamydospores. The brand spores are resting spores; they are scattered by the wind, and after an interval of rest they germinate, producing conidiospores of a basidium-like type.

The spores of *U. hypodytes* are the cause, according to most authors, of a peculiar affection found among workers who have to do with the cutting, etc., of *A. donax.* This affection is called 'frienite,' or 'frien disease.' The patient complains of symptoms somewhat resembling hay-fever, sneezing, headache, etc., and, in addition, shows an erythematous eruption on the uncovered part of the body, and often also on the genital organs, which may become greatly œdematous.

According to a few other observers, the cause of this peculiar disease is to be found, not in the spores of *Ustilago*, but in an insect—*Aclerda berlesei*—which often swarms on various canes. The workers, in manipulating the canes, squash some of these insects. The irritating juice exuding from the squashed insects produces a dermatitis of an erythematous type.

ORDER HYPHOMYCETES (MUCIDINEES OR FUNGI IMPERFECTI).

This order contains groups of very different fungi, the botanical position of which cannot be conclusively made out in the present state of our knowledge. For the classification of these fungi it is necessary to take into account, not only their morphological botanical characters, but also their biological characters and pathogenic properties.

The following genera of Hyphomycetes contains species parasitic in man : (1) *Discomyces* Rivolta 1878 ; (2) *Madurella* Brumpt 1905 ; (3) *Indiella* Brumpt 1905 ; (4) *Trichothecium* Link 1824 ; (5) *Monilia* Persoon 1801 ; (6) *Sporotrichum* Link 1809 ; (7) *Trichosporum* Behrend 1890 ; (8) *Microsporoïdes* Neveu-Lemaire 1906 ; (9) *Pityrosporum* Sabouraud ; (10) *Hemispora* Vuillemin 1906 ; (11) *Malassezia* Ch. Robini 1853 ; (12) *Foxia* Castellani 1908.

Genus Discomyces Rivolta 1870.

Some mycelial filaments terminate in club-like formations, and show a radial arrangement ; masses of mycelium give origin to peculiar granules or ' grains ' of various consistence and colour, according to the different species. These fungi are parasitic in man and lower animals, and may live as saprophytes or parasites on plants.

Discomyces bovis Harz 1877.

Synonyms.—*Actinomyces bovis* Harz 1877, *Discomyces bovis* Rivolta 1877, *Nocardia actinomyces* Toni and Trevisan 1889, *Streptothrix actinomyces* Rossi-Doria 1891, *Oospora bovis* Sauvageau and Radais 1892, *Actinomyces bovis sulphureus* Gasperini 1894, *Nocardia bovis* R. Blanchard 1895, *Streptothrix israeli* Kruse 1896, *Cladothrix actinomyces* Mace 1897, *Discomyces bovis* R. Blanchard 1900, *Streptothrix spitzi* Lignières and Spitz 1903.

This *Discomyces* is the cause of human and bovine actinomycosis, and of the actinomycotic mycetoma. The fungus lives parasitic in most tissues, in which it gives rise to degenerative and purulent changes. In the pus small, soft yellow granules—so-called ' sulphur grains '—are seen. These sulphur grains consist of masses of mycelium. At the periphery of the granule the threads are radially arranged, and their free extremities become club-like, 10 to 20 millimetres in length and 8 to 10 millimetres in breadth. These peculiar club-like formations had been considered by some authors to be degeneration forms of the fungus, but Brumpt has demonstrated that they are young active forms, and disappear in old granules.

Cultures.—The fungus grows easily on agar, glycerinated agar, gelatine, broth, potato, and other media. Optimum temperature, 35° to 37° C. On solid media the colonies develop fairly rapidly, and have a coarse granular appearance. The fungus is Gram-positive but not acid fast.

Saprophytic Life.—The fungus is often found as saprophytic on the spikelets of some cereals (*Phleum pratense* Linnæus, *Hordeum murinum* Linnæus, etc.).

Varieties.—Gasperini describes three varieties of *Discomyces bovis* —*D. bovis sulphureus*, *albus*, and *luteo-roseus*. Caminiti has described a variety which he thinks may be a new species.

Other authors have described as a separate species (*D. israeli*) a *Discomyces* found in several cases of human actinomycosis. According to Wright and the majority of authors, *D. israeli* is identical with *D. bovis*.

Discomyces försteri Cohn 1874.

Mycelial threads very slender, non-ramified, often terminating in a chain of rod-like or coccus-like elements. Masses of the fungus form some peculiar whitish bodies, which have been occasionally found in the lachrymal canals of man.

Discomyces rosenbachi Kruse 1896.

Synonym.—*Streptothrix rosenbachi* Kruse 1896.

Isolated by Rosenbach in a skin affection called by him 'erysipeloid.' Mycelial threads very slender; some terminate in club-like swellings. Can be cultivated on the ordinary media.

Discomyces asteroïdes Eppinger 1890.

Synonyms.—*Cladothrix asteroïdes* Eppinger 1890, *Streptothrix eppingeri* Rossi-Doria 1891, *Oospora asteroïdes* Sauvageau and Radais 1892, *Nocardia asteroïdes*. R. Blanchard 1895, *Discomyces freeri* Musgrave and Clegg 1907.

Found in mycetoma and in cases of abscess of the brain. Mycelial threads very slender (0·2 μ wide); the mycelial articles become easily dissociated, when they look bacillus-like. This fungus is easily cultivated on ordinary media; obligative aerobe. Inoculations in the rabbit and guinea-pigs produce a form of pseudo-tuberculosis.

Discomyces brasiliensis Lindenberg 1909.

Found by Lindenberg in a case of mycetoma of the leg. Small white-yellowish, soft, moriform granules (0·1 to 0·5 millimetre), consisting of very delicate ramified mycelial tubes (0·0521 μ in diameter). Easily cultivated. Pinkish growth on Sabouraud's medium.

Discomyces maduræ Vincent 1894.

Synonyms.—*Streptothrix maduræ* H. Vincent 1894, *Nocardia maduræ* R. Blanchard 1895.

It causes Vincent's white mycetoma, very commonly found in Africa and Asia. The 'grains' which are found in the pus of such cases are soft, white, or slightly yellowish, and have a *mulberry-like* surface. At the periphery of the grains radiating filaments are found, but claviform swellings are usually absent; mycelial threads are always very slender (1 to 1½ μ). The fungus can be grown on the ordinary media; facultative aerobe. On glycerinated agar it forms discoid colonies, white in the centre and reddish at the periphery. In the cultures the mycelial threads are as slender as in the grains. Some of the mycelial threads have at their extremities short chains of small conidial elements. Gram-positive, but not acid fast.

It is to be noted that this fungus very rarely produces bone lesions. Most strains are inoculable into monkeys.

Genus Madurella Brumpt 1905.

One species only.

Madurella mycetoma Laveran 1902.

Synonym.—*Streptothrix mycetomi* Laveran 1902.

This causes a variety of mycetoma with black, irregular-shaped grains; mycelial threads of a variable diameter (between 1 and 10 μ); septated, ramified; secrete a dark substance. After some time the mycelial threads become organized into *sclerotia*, containing roundish bodies (8 to 10 μ in diameter), which are probably chlamydospores.

Genus Indiella Brumpt 1905.

White thallus vegetating in various animal tissues (bones, muscles, connective tissue); mycelial threads 1 to 5 μ wide, occasionally as much as 10 μ; septated, ramified; no secretion of pigment. These filaments, by massing together, form grains comparable to sclerotia containing chlamydospores.

Indiella mansoni Brumpt 1905.

White mycelium; young filaments very slender (1½ to 2 μ); older ones thicker (3 to 5 μ wide). Presence of many chlamydospores, generally terminal. The grains or sclerotia are very small (0·2 to 0·25 millimetre in diameter), hard, white. This fungus gives rise to a variety of white mycetoma found in India.

Indiella reynieri Brumpt 1905.

The sclerotia or grains are characteristic; small (less than 1 millimetre); white; coiled up like the excrementa of earth-worms. This fungus causes a variety of white mycetoma.

Indiella somaliensis Brumpt 1905.

Mycelial threads extremely thin (0·5 μ); when old, often take a moniliform appearance; numerous chlamydospores; the grains, formed by dense felting of mycelial threads, are whitish or yellowish, small (about 1 millimetre), very hard. *I. somaliensis* cannot be grown. According to Brumpt, another *Discomyces*, easily grown, may be found living symbiotically in the tissues with *I. somaliensis*.

Genus Trichothecium Link 1824.

Fertile hyphæ are erect, grouped together, each terminating in an oval, pear-shaped, or globular conidium. The only species so far observed in man is *Trichothecium roseum.*

Trichothecium roseum Persoon 1801.

Synonyms.—*Trichoderma roseum* Persoon 1801, *Sporocephalum roseum* Persoon 1801, *Puccinia rosea* Corda 1837.

This species vegetates on decaying vegetable matter ; the colour is at first white, then pinkish. Each fertile hypha terminates in a pear-shaped conidium, 10 to 20 μ in length and 8 to 12 μ in breadth.

This fungus has been found in a few cases of otomycosis.

Genus Monilia Persoon 1801.

Fertile hyphæ are erected, bearing at their extremities short chains of large roundish conidia.

Monilia candida Bonorden.

Commonly found vegetating in decomposing vegetable matter; occasionally seen parasitic in Mammalia, giving rise to white patches on the tongue and buccal mucosa, somewhat similar to human *thrush.* Once found in a child in some white patches present on the tongue. Mycelium 1 to 1½ μ in breadth; conidia roundish, smooth, 7 to 8 μ in diameter.

Monilia kochi Saccardo 1885.

Synonym.—*Rhodomyces erubescens* Aster 1900.

Morphologically similar to *M. candida* ; grows well on sugar media, where it produces pinkish colonies; was observed by Wettstein in a case of chronic acid dyspepsia.

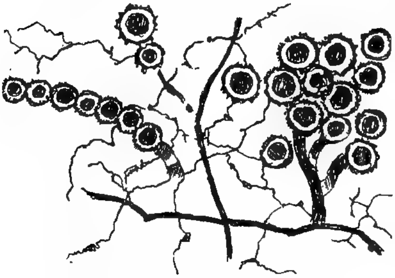

FIG. 280.—MONILIA MONTOYAI. (After Montoya y Florez.)

Monilia montoyai Castellani 1907.

Discovered by Montoya in cases of white pinta. Some fertile hyphæ are much thicker than others ; the spores are large, globular (5 to 7 μ), and contain a large nucleus. Grows well on sugar media, giving rise to white, creamy colonies which rapidly fuse together.

Genus Sporotrichum Link 1809.

During parasitic life the fungi of this genus appear as yeast-like cells. In cultures they show abundant septate, ramified mycelium, and oval or roundish spores. The dermatomycoses caused by these fungi are called sporothricoses; they are often characterized by the presence of gumma-like swellings.

Sporotrichum schenki Hektoen and Perkins 1900.

Easily grown on glucose and other sugar media. Colonies brownish, with an irregular surface; abundant mycelium; spores oval, 3 to 5 μ in length; pathogenic to mice.

Sporotrichum beurmanni Matruchot and Ramond 1905.

Easily cultivated on sugar media; colonies at first are often whitish, soon to become brownish, and even black; mycelial threads slender, frequently less than 2 μ wide; very much ramified; spores ovoid (3 to 5 μ long and 2 to 4 μ wide); very pathogenic for mice.

Sporotrichum indicum Castellani 1908.

Found by Castellani in two cases of tropical sporotrichosis. Closely resembles the *S. beurmanni;* the mycelial threads are somewhat larger, between 2 and 3 μ wide; spores roundish (3 to 5 μ in diameter) or oval (4 to 5 μ long and 3 to 4 μ in breadth). Colonies on maltose agar may be of various colours—greyish, light brownish, dark brownish, black.

Genus Trichosporum Behrend 1890.

These fungi live parasitic on the surface of the hairs, but do not penetrate into their interior; during their parasitic life they vegetate under the form of large oval or roundish elements. Saprophytically (cultures) they vegetate forming mycelial threads and spores.

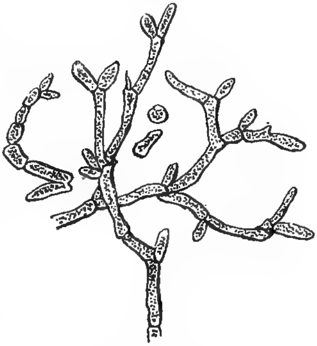

Fig. 281.—Trichosporum. (After Vuillemin.)

Trichosporum giganteum Behrend 1890.

This is the cause of *piedra* of Columbia; develops on the surface of the hair under the form of large polyhedric cells 12 to 15 μ in diameter. Masses of the fungus form hard nodules along the hair. The fungus is easily grown on various media. In cultures the mycelial threads are septated, cylindrical, between 1 and 4 μ wide. The spores are of various dimensions, between 2 and 12 μ.

Trichosporum beigeli Rabenhorst 1867.

Synonyms.—*Pleurococcus beigeli* Rabenhorst 1847, *Sclerotium beigelianum* Hallier 1868, *Hyalococcus beigelii* Schroeter 1886, *Chlamydotomus beigelii* Trevisan 1889, *Micrococcus beigelii* Migula 1900, *Trichosporum beigelii* Vuillemin 1901.

This fungus has been found in Europe several times in nodosities of the hairs of the moustache. It lives parasitically under the form of ovoid or polyhedral elements massed together on the surface of the hair. These ovoid or polyhedral elements are much smaller than those of the preceding species, their maximum diameter varying between 3 and 4 μ. It is easily cultivated on ordinary media. In cultures mycelial threads are found, septate, slender (1·75 to 2 μ). In old cultures chlamydospores are to be seen.

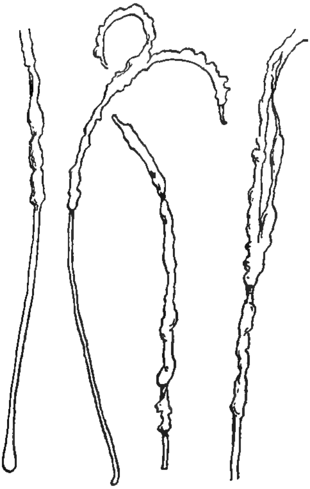

FIG. 282.—HAIR AFFECTED WITH TRICHOSPOROSIS. (After Vuillemin.)

Trichosporum ovoïdes Behrend 1890.

Found by Behrend in the nodosities present on the moustache of a European patient; vegetates parasitically on the surface of the hair under the form of ovoid elements; 3 to 4 μ long and 1½ to 2½ μ wide. Grows easily on culture media; on potatoes the colonies are white, while the medium takes a brownish-black colour.

Trichosporum ovale Unna 1896.

Found by Unna in the nodosities present on the moustache of a European patient. Very similar to *T. ovoïdes*; in cultures, however, the mycelial threads are often corkscrew-like, and the spores have thick walls. On potatoes the colonies are white-yellowish, and the substratum takes a brownish-black colour.

Genus Microsporoïdes

Neveu-Lemaire 1906.

One species only.

Microsporoïdes minutissimus

Burchardt 1859.

Synonyms.—*Microsporum minutissimum* Burchardt 1859, *M. gracile* Balzer 1883, *Sporotrichum minutissimum* Saccardo 1886, *Discomyces minutissimus* P. Verdun 1907.

Mycelial threads extremely thin (0·6 μ); seldom ramified. The mycelial segments get easily dissociated, and have then the appearance of bacilli. Has not yet been cultivated; is the cause of erythrasma.

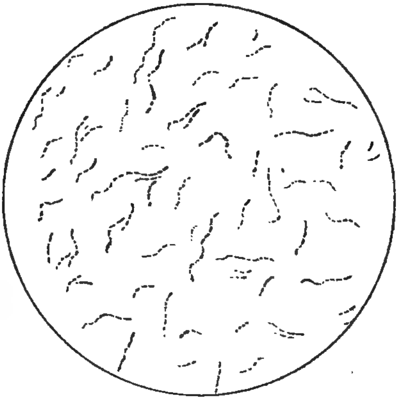

FIG. 283.—MICROSPOROÏDES MINUTISSIMUS BURCHARDT. (After Neven-Lemaire.)

Genus Pityrosporum Sabouraud 1895.

Oval or roundish cells, somewhat yeast-like; no mycelium; cannot be grown artificially.

Pityrosporum ovale Bizzozzero 1882

Synonyms.—*Saccharomyces ovalis* Bizzozzero 1882, *Pityrosporum malassezi* Sabouraud 1895. Usual term: bottle bacillus of Malassez.

This organism was first described by Bizzozzero, who considered it to be a *Saccharomyces*. Malassez and Sabouraud associated this organism with the etiology of pityriasis simplex capitis and pityriasis alba.

Its shape somewhat resembles a budding yeast or a flask. The size varies greatly; the maximum diameter of some individuals may be as much as 10 to 15 μ, but much smaller forms (3 to 5 μ) are found.

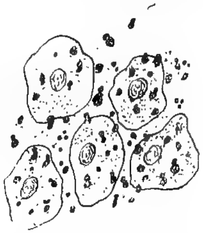

FIG. 284.—PITYROSPORUM OVALE. (After Sabouraud.)

Pityrosporum cantliei Castellani 1908.

Synonym.—*Saccharomyces cantliei* Castellani 1908.

Somewhat similar to *Pityrosporum ovale*, but the cells are generally roundish and on the average larger (5 to 16 μ). Probably the cause of a variety of seborrhœa of the scalp occasionally met with in children in the tropics.

Genus Hemispora Vuillemin 1906.

One species.*

Found by Vuillemin parasitic on *Aspergillus repens*, forming white discs (0·5 to 2·5 millimetres in diameter), which present, in relief, stellar or marguerite-like brown structures. Composed of conidiophores, each conidiophore terminates in a vesicle-like structure (protoconidium), which later divides into several spore-like segments (dentero conidia). Can easily be cultivated on artificial media, the growth being cerebriform, and not characteristic. This parasite has been observed in man in gumma-like swellings.

Genus Malassezia Ch. Robin 1853.

Mycelium of various shape and size; non-ramified; spores collected in bunches like grape-bunches; only the parasitic stage known.

Malassezia furfur Ch. Robin 1853.

Synonyms.—*Microsporon furfur* Ch. Robin 1853, *Sporotrichum furfur* Saccardo 1886, *Malassezia furfur* Baillon 1889, *Oidium furfur* Zopf 1890, *O. subtile* Kotliar 1892.

Mycelium abundant, septate, non-ramified; some mycelial threads are much larger than others; the breadth varies between 3 and 4 μ. The spores are roundish (3 to 5 μ in diameter), and run into clusters.

Attempts at cultivation have failed. It is the cause of pityriasis versicolor.

Malassezia tropica Castellani 1905.

Synonym.—*Microsporon tropicum* Castellani 1905.

Mycelial threads generally thick (3 to 5 μ wide), with numerous swellings, constrictions, and other irregularities of shape; spores

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* *Hemispora stellata* Vuillemin 1906.

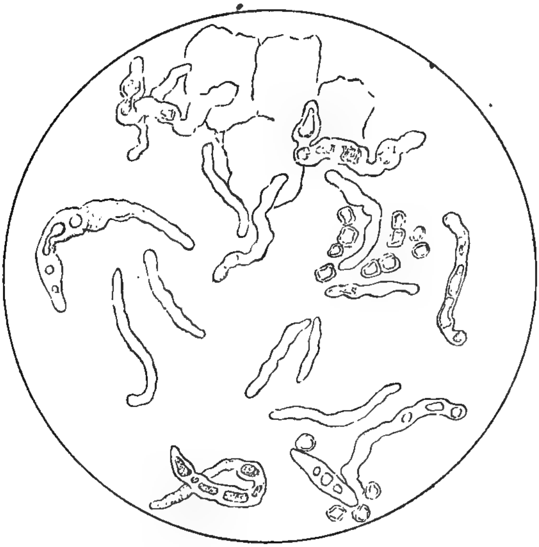

FIG. 285.—MALASSEZIA TROPICA.
(From a fresh preparation in liquor potassæ. Old case.)

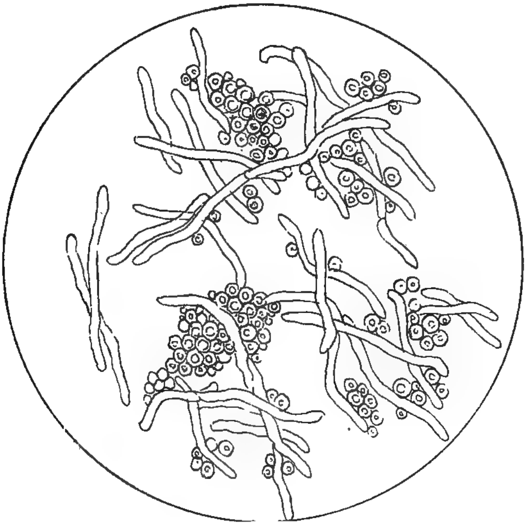

FIG. 286.—FOXIA MANSONI.
(From a fresh preparation in liquor potassæ. The mycelial tubes are in reality not so regular in outline as in this drawing.)

roundish (4 to 5 μ), with a double contour ; are often collected in clusters. The fungus does not grow on artificial media. It is the cause of tinea flava or pityriasis flava of tropical climates.

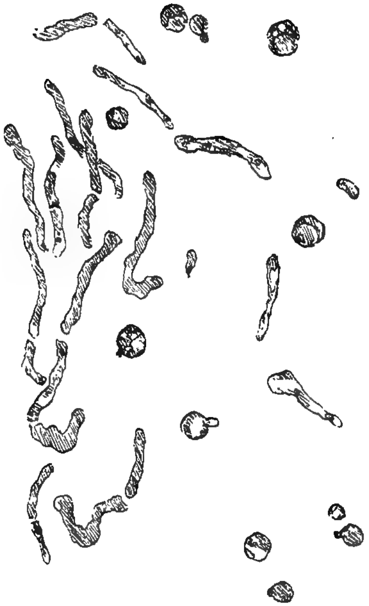

FIG. 287.—FOXIA MANSONI.
(From a preparation stained with fuchsin.)

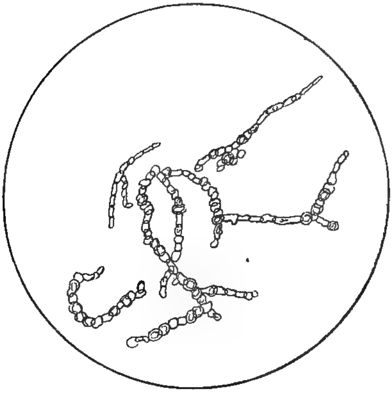

FIG. 288.—FOXIA MANSONI.
(Hanging-drop culture.)

Genus Foxia Castellani 1908.

One species.

Foxia mansoni Castellani 1905.

Synonym.—*Microsporon mansoni* Castellani 1905.

Mycelial articles straight or variously bent, 2·5 to 3 μ wide;

non-ramified spores large, globular, 5 to 10 μ in diameter, collected in clusters; spores are occasionally seen budding.

The fungus is easily grown on maltose and other sugar agars, and also on ordinary agar. On maltose and ordinary agar it gives rise to greenish-black granular colonies, which later fuse into a jet-black mass. It slowly liquefies gelatine after three or four weeks. In hanging-drop cultivations short mycelial threads are seen, terminating in long strings of roundish conidia. Lateral conidia are not seen, nor spindle-shaped organs, as found in *Trichophytons* and *Microsporons*.

This fungus is the cause of tinea nigra.

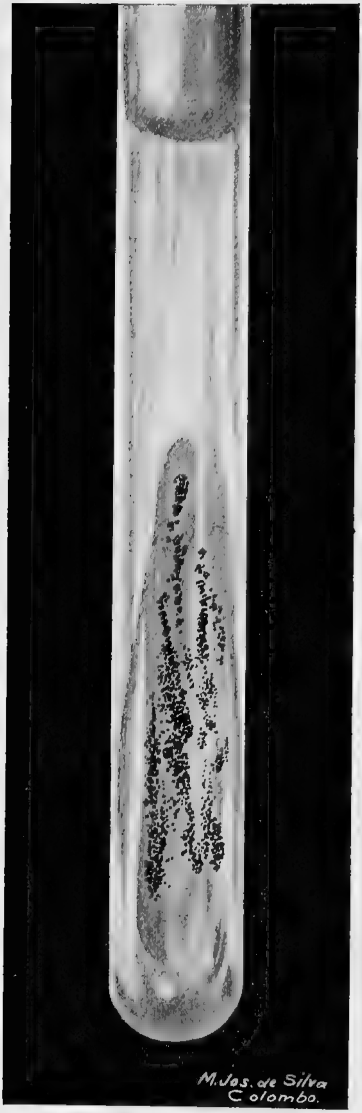

FIG. 289.—FOXIA MANSONI.
(Young agar culture.)

REFERENCES.

The] best systematic work on vegetal parasites is Blanchard's 'Parasites végétaux à l'Exclusion des Bactéries,' in the 'Traité de Pathologie Générale' of Bouchard. Excellent textbooks are Perroncito's 'Parasitologia Umana,' Torino, 1906; Neveu-Lemaire's 'Parasitologie Humaine,' Paris, 1906; Verdun's 'Précis de Parasitologie Humaine,' Paris, 1907. The current literature is mostly to be found in the *Archives de Parasitologie*, edited by Blanchard; in the *Centralblatt für Bakteriologie* and in the principal journals of dermatology.

PART III

THE DISEASES OF THE TROPICS

SECTION A

FEVERS

CHAPTER XXIII

MALARIA

Synonyms — Definition — History — Ætiology — Climatology — Pathology —Clinical description—Acute malaria—Quartan fevers—Tertian fevers—Subtertian fevers—Chronic malaria—Latent malaria—Masked malaria—Congenital malaria—Complications—Sequelæ—Diagnosis—Prognosis—Treatment—Prophylaxis—References.

Synonyms. — Ague, Paludism, Marsh fever, Remittent fever, Intermittent fever; Climatic, Jungle, Hill, Mountain and Coast fever; Fièvre palustre (French), Wechselfieber, Kaltesfieber, Malaria (German), Paludismo, Malaria (Italian).

Malaria used to be known by many local names in different countries, such as Kurunegala fever and Dambul fever in Ceylon; Roman fever, Sierra fever, etc.

The term 'malaria' is derived from the Italian *mal aria*, meaning bad air.

Definition.—Malaria is a term employed to signify a group of acute specific fevers caused by the protozoan parasites *Plasmodium malariæ, P. vivax,* and *Laverania malariæ* living in the blood of man, and disseminated by the agency of certain species of mosquitoes, in which these parasites undergo part of their life-history.

It will be obvious from the above definition that there are three distinct types of malarial fever, the first caused by *P. malariæ,* the second by *P vivax,* and the third by *L. malariæ.* It will be observed that the term 'blood of man' is used in the definition. This is because at present we are not aware that the above-mentioned parasites are capable of living in any other vertebrate.

History.—The history of malarial fever has already been sufficiently noted in Chapter I. (p. 11), to which reference should be made.

The important questions which at present require further elucidation are:

1. The nature and action of the toxins of the disease, especially with regard to the hæmolysins.
2. The formation of antibodies.

3. The form in which the malarial parasite lies dormant in the human body (with special reference to the parthenogenesis of the macrogametocyte).

4. Whether Schaudinn is correct in believing that the eggs of the mosquito can become infected, and if so, whether that infection is capable of being spread by the next generation of mosquitoes.

5. Whether any mosquito other than the Anophelinæ carry the parasites.

6. Whether there is any animal other than man in which the parasites live in nature.

Ætiology.—EXCITING CAUSES.—Malarial fevers are produced by the parasites *Plasmodium malariæ* Laveran 1881, *P. vivax* Grassi and Feletti 1890, and *Laverania malariæ* Grassi and Feletti 1890, because they are always found in the blood or organs of persons suffering from the disease, and can be injected into healthy persons, producing in them typical fevers, the different stages of which correspond to the stages of the life-cycle of the parasite. These parasites can be spread from human being to human being by mosquitoes, in whose bodies they undergo development as already described. Infected mosquitoes can convey the parasites to healthy persons, living in either non-malarial or malarial climates, by their bites, producing attacks of fever typical for the type of parasite with which the mosquito was infected. The classical experiment is the infection of Sir Patrick Manson's son with tertian malaria by means of infected Anophelines sent from Rome to London.

There are, therefore, three factors necessary for the production of malarial fever: (1) the blood parasite; (2) the mosquito; (3) man.

1. **The Blood Parasite.**—We have drawn attention to three parasites in connection with malaria, and we believe these to be the only three at present known to cause the fevers, but it is necessary to say that this view is by no means universal. Some authorities believe in a quotidian form of fever due to a species of *Laverania*, or to two separate species of the same genus. These parasites, however, if they exist as distinct species, which we believe to be very doubtful, have not come within our observation, and we therefore agree with those writers who only acknowledge the three types mentioned above.

The descriptions of the structure and life-histories of these parasites have been given in Chapter XII., and need not be referred to here.

The parasites are introduced into the human body as sporozoites, which pass from the salivary glands down the hypopharyngeal canal of the mosquito's proboscis into the blood when a human being is bitten by an infected Anopheline.

Once in the blood, three possibilities confront the parasites: they may either be killed and no infection result, or they may remain dormant in some form in the spleen, and not develop until predisposing causes, by lowering the vitality, give them opportunity, or they may at once proceed to develop and give rise to fever.

In this latter event, there is usually an interval between the period of the bite and the attack of fever, for it is evident that in order to influence the metabolism of the body so profoundly as to produce a rise of temperature, a certain amount of toxin must be generated. This requires a definite number of parasites, and hence the incubation period may be short if many parasites are simultaneously inoculated by the mosquitoes, or long if but few. As a rule it may be said that some nine to twelve days are required for the development of a sufficient number of parasites to produce fever.

During the incubation period, however, there may be slight symptoms of lassitude, or pains in various parts of the body coming on at regular intervals, and often not much regarded, as they may pass off quickly. We are inclined to consider these as being due to parasites as yet not numerous enough to produce fever, and we think these symptoms of importance, as an attack of fever may be prevented by the prompt administration of quinine. This subject will, however, be further discussed under the Pathology of Latent Malaria.

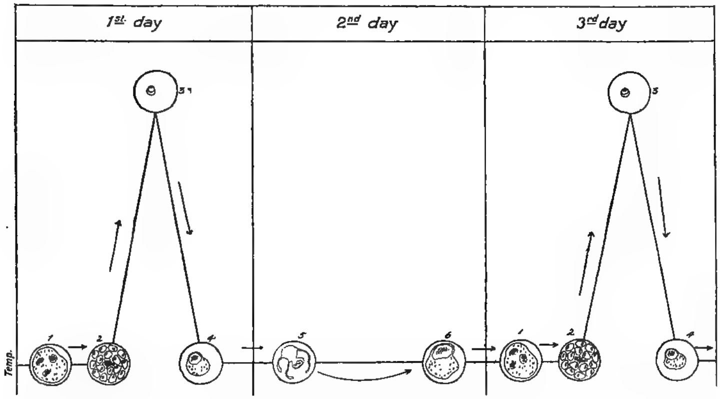

FIG. 290.—DIAGRAM OF A TEMPERATURE-CHART IN SIMPLE TERTIAN MALARIAL FEVER.

1, Schizont, with commencing sporulation ; 2, sporulating schizont ; 3, young trophozoite ; 4, 5, trophozoites ; 6, schizont.

The life-history of the parasite has a definite relationship to the disease, as can be noted by studying the diagrams. The rise of body-temperature is always associated with the sporulation of the parasite and the liberation of pyrogenetic toxins, the apyretic interval with the growth and maturation of the parasite in the red corpuscle. The pigmentation of the cells and organs is due to the hæmozoin liberated by the disruption of the infected red cell. The liberated spores attack new erythrocytes, and so the numbers of the parasites may increase, until in certain pernicious cases it appears as though the majority of the red cells were infected with parasites, and, indeed, two or more may be noted in one cell. Such a condition must, of course, lead to death.

But this does not by any means always happen; for it is well known that a malarial, especially a quartan, fever may wear itself out, the attacks becoming less and less severe until they cease.

This would appear to be due to acquired immunity, which no doubt explains the known fact that the European in West Africa on first arrival generally suffers from repeated attacks of fever, but he gradually becomes partially immune, and can then live there, with care, for years. Further, it would certainly explain, in part, the relative immunity of the native races in that region who are infected from earliest childhood, and no doubt this is the true cause of the racial immunity which some allege to exist. It is now known that the merozoites can, although very rarely, penetrate the placenta and infect the fœtus, giving rise to congenital malaria.

The three parasites produce very different results, apparently due to their habitats. Thus *Plasmodium malariæ* and *P. vivax* as a rule live mainly in the circulating blood, in which the former sporulates, while the latter develops in the spleen: their toxins will therefore produce general symptoms. *Laverania malariæ*, on the other hand, seems to affect the red corpuscles so profoundly that they are liable to adhere to the walls of the capillaries of the organs in which the parasite sporulates. Hence this parasite may produce severe local symptoms, due to the mechanical blocking of capillaries or to the more intense local action of the toxin, or to both of these causes, and therefore it is associated with what are called the pernicious fevers—that is to say, the fevers which produce severe effects on one or more organs—*e.g.*, on the brain, causing coma or paralysis; or on the pancreas, causing hæmorrhagic pancreatitis.

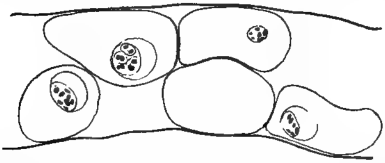

FIG. 291.—LAVERANIA MALARIÆ IN RED CORPUSCLES BLOCKING A BRAIN CAPILLARY IN THE CEREBRAL TYPE OF PERNICIOUS MALARIA.

At the onset, all three types of fever are apt to be irregular, because the parasites are of different ages, due to the different times of inoculation, but they settle down to a regular type, possibly because the amount of antitoxin generated is able to kill off those parasites which do not conform to the age-period of the majority. Sometimes, however, two distinct broods may exist, producing double fevers, or three distinct broods, causing triple fevers.

The malarial parasite acts not merely by destroying the corpuscle in which it lives and by altering the metabolism of the body by the pyretic toxin of Rosenau and his collaborators, but it also has a hæmolytic toxin, first described by Casagrandi and De Blasi, which destroys the red corpuscles, thus throwing more work on to the liver and leading to excessive formation of bile, with, as a result, diarrhœa and urobilin in the urine. If the blood-destruction is excessive, the liver is unable to convert the whole of the hæmoglobin liberated into bile, with the result that some may be left unaltered, and may produce hæmoglobinuria.

It appears, however, that an antitoxin is quickly formed, of the nature of an anti-auto-complement, which neutralizes this hæmolysin, and it further appears, from the experiments of Casagrandi on pigeons infected with *Hæmoproteus* (*Halteridium*), that the antitoxin may be a cause of the natural disappearance of the parasites and the cure of the disease. Of course this antitoxin is produced by the cells of the body, and anything which lessens its formation, such as starvation, gives the parasite a chance to grow and cause disease. Thus Casagrandi found that out of twenty-one birds infected in 1904, ten were still infected in 1905. On semi-starving two of these, he produced relapses, while two others treated with antitoxin obtained from guinea-pigs inoculated with pigeon's blood did not relapse.

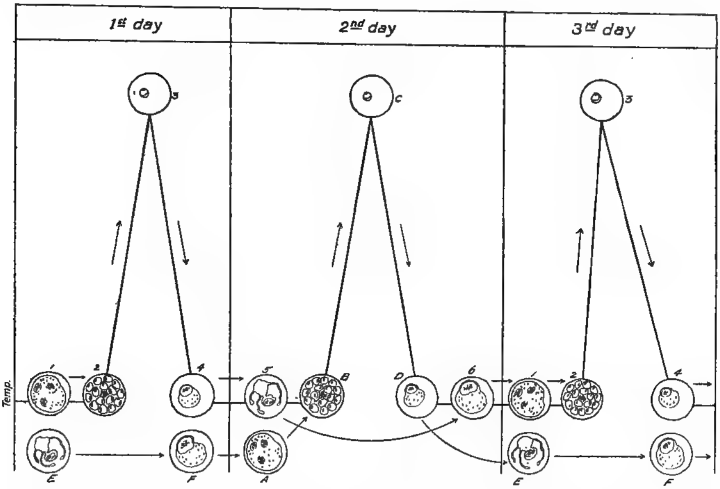

FIG. 292.—DIAGRAM OF A TEMPERATURE-CHART IN DOUBLE TERTIAN MALARIAL FEVER.

The fever of the first and third days is due to one brood of parasites and that of the second day to another brood.

1, Schizont of first brood; 2, sporulating schizont of first brood; 3-5, trophozoites of first brood; 6, schizont of first brood; *A*, schizont of second brood; *B*, sporulating schizont of second brood; *C-E*, trophozoites of second brood; *F*, schizont of second brood.

It will thus be seen that a relapse may be due entirely to predisposing causes which lower the vitality of the body and prevent the production of sufficient quantities of the antitoxin.

Besides the difference pointed out above as to the place of sporulation, there is also a great difference in the time occupied by the cycle of schizogony. *Plasmodium malariæ* requires seventy-two hours to complete its schizogony, or, in other words, it will liberate its toxins and cause an attack of fever in its human victim every seventy-two hours, while in an infection with only one brood of parasites the intervening period will be without fever. This intermission is so marked that it was noted by the ancients, and formed one of their types of intermittent fever, and as the attack of fever occurred on the fourth day, after an interval of seventy-two hours, it was called a 'quartan,' or fourth-day fever, and as such is clearly described by Hippocrates. *Plasmodium vivax* requires forty-eight hours to complete its schizogony, and in single infections produces fever every forty-eight hours—*i.e.*, on the third day—and therefore this type of fever is called 'tertian.'

Laverania malariæ, on the other hand, does not appear to be so regular in the time of its schizogony, and may require from thirty-six to forty-eight hours for the purpose; but though typically producing a tertian fever, the effects due to its sporulation in the organs are much more severe and protracted than those produced by *P. vivax*. Clinically, therefore, there are two types of tertian malarial fever—a benign and a malignant. The former, caused by *P. vivax*, is generally called 'tertian malarial fever,' while the latter, caused by *L. malariæ*, is called 'subtertian malarial fever,' or malignant tertian.

In addition to these clearly-defined parasites, two others have been described by various authors, and have been named *Hæmamœba præcox* and *H. immaculata* by Grassi and Feletti. The former was said to be pigmented, and the latter to be unpigmented. These parasites require only twenty-four hours for the completion of the cycle of schizogony, consequently they cause fever every twenty-four hours, which is therefore of the nature of a 'quotidian malarial fever.' Many authorities, with whom we agree, consider these parasites to be only stages in the development of *Laverania malariæ*. Quotidian fever can be produced by three broods of *P. malariæ*, or two of *P vivax* or *L. malariæ*, and does not require a special quotidian parasite.

Therefore there are only three parasites and three classes of fever to be considered—viz.: (1) *Plasmodium malariæ*, causing quartan malarial fever; (2) *P. vivax*, causing tertian malarial fever; (3) *Laverania malariæ*, causing subtertian malarial fever.

2. **The Mosquito.**—With regard to the Anophelinæ, we know positively that some can carry the germ while others cannot. Further, it appears quite evident that *Culex* and *Stegomyia* are not carriers of malaria. Daniels, as we have already stated, is inclined to suspect the Ædinæ as being possible disseminators of malaria in jungles, but there is no complete proof of this. Therefore we have at present only the Anophelinæ to consider.

We have already pointed out the various species of Anophelinæ which can carry the parasites, but the presence of these mosquitoes does not indicate that there must be malaria in the locality, which is an important matter, to which Celli was the first to call attention.

England, for example, though it possesses three species of the Anophelinæ—viz., *Anopheles maculipennis* Mg., *A. bifurcatus* L., and *A. nigripes* St., of which the two former certainly can carry malaria—is practically free from disease. Nuttall, Cobbett, and Strangeways-Pigg believe that this condition has been arrived at by the reduction of the numbers of the mosquitoes by drainage.

On the other hand, there is no evidence of the existence of malaria without some of the Anophelinæ. On the contrary, there is evidence that where there are no Anophelinæ there is no malaria. Further, it is highly probable that the endemic malaria of Mauritius and Réunion is due to the introduction of *Pyretophorus costalis* Loew, as has been pointed out by Ross. There is also the evidence that in places where successful anti-anopheline measures have been carried out, as in Ismalia, malarial fever has ceased to exist.

In order that there may be plenty of these insects, there must be a certain degree of warmth; for as a rule they hibernate in the winter of the temperate zone, coming out in the spring, and increasing in numbers, to reach a maximum in the warm days of autumn. In the tropics, of course, the heat is present all the year round. Heat alone, however, will not suffice for the mosquito, for there must be water for the development of the larvæ and pupæ. Hence, in the dry season in the tropics, there may be few mosquitoes visible, while their numbers will increase remarkably after the rains. In the dry season the mosquitoes, and their larvæ, æstivate, and wait for more suitable conditions.

There is, however, a third factor to be considered, and that is the effect of the temperature upon the parasite in the mosquito. For ages it has been noted that the fevers due to *P. malariæ* and *P vivax* occur in the temperate zone in the earlier period of the year—*i.e.*, in the spring—while the worst fevers, due to *L. malariæ*, do not occur until the summer or autumn. This point has been carefully studied by Grassi, Janscó, and others, and the result of their experiments tends to show that temperature has most effect upon the oökinete before it pierces the wall of the stomach of the mosquito and becomes encysted. It would appear that if the temperature is below 15° C. to 16° C., no further development of the oocyst will take place in any form of parasite. Further, *P. malariæ* will develop at a lower temperature than the other two, while *P vivax* will also develop at a low temperature, but *L. malariæ* requires a distinctly higher one.

This may be the reason of the scarcity of *L. malariæ* in the temperate zone, except in the summer and autumn, and its common occurrence in the tropics, and, possibly, this is also the reason of the rarity of *P. malariæ* in the low country of the tropics, where its presence in the hills is common.

Here may also lie the explanation of the universal distribution of *P. vivax* in both the tropics and temperate zone; for Janscó's researches show that it can develop through a wide range of temperatures.

But these are not the only factors concerning the Anophelinæ and malaria, for Schaudinn showed that the mosquito eggs may be infected by the malarial parasites, and this at once raises the question whether they cannot be carried via eggs, larvæ, and pupæ into a second generation of mosquitoes. If so, this would explain some outbreaks of malaria.

Another point of importance is the fact that when new lands are opened, it is asserted that people suffer more severely from malaria than can be explained by any theory brought forward at present. For example, it is stated that if a zone of forest on a steep hillside be burnt in the dry season, and then cleared by coolies, who return every night to the quarters where the other estate coolies also sleep, these clearing-coolies will suffer severely from malaria, while their fellows working on other portions of the estate will be but little affected. The explanation of this is not that emanations have arisen from the soil and invaded the bodies of the coolies—indeed, after the description of the life-history of the malarial parasite already given, this would be a *reductio ad absurdum*—but merely that the exposure to the sun or the harder work has lowered the vitality of these coolies, and has given the germs already in their system a chance to develop.

It has also long been thought that the mechanical opening of new ground by digging produced the disease, but Ross has pointed out that in Mauritius the digging of earth for years caused no malaria, until some new factor was introduced, which occurred in the sixties of last century ; this factor we now know to be the introduction of *Pyretophorus costalis* into the island.

When an attack of malarial fever occurs in a person living in a place where there are no Anophelinæ, it is the result of infection obtained in some other place where these mosquitoes are to be found.

It may safely be concluded that, as far as our present knowledge goes, certain of the Anophelinæ are the only carriers of malaria, and upon this public prophylaxis must be based.

A female mosquito, apparently, can live for at least a month (Ross), if not longer. This does not include such dormant periods of its life as the hibernation in the cold or æstivation in dry seasons, when it may live for a long time in damp places.

The eggs of the Anophelinæ are laid only in natural collections of water supplied with water-plants, such as the back eddies of streams, close under the banks, which are especially good breeding-places. The young imagines, apparently, do not usually travel, but remain near the place where they are developed. Exceptionally, they can be carried long distances by ships, trains, coaches, carts, etc., but this is the exception and not the rule. Winds do not appear to carry them far, as they generally take shelter from a high wind. The natural enemies of the Anophelinæ are numerous, including all insectivorous animals, such as bats and birds, together with fish, which eat the larvæ.

The Anopheline not merely carries the germ, but because of its length of life, a single individual may be capable of infecting several human beings; for it must be remembered that there is no proof that the mosquito is in any way deleteriously affected by the malarial parasite.

3. **Man.**—The female Anopheline requires blood for the purpose of providing its eggs with sufficient nourishment, and will, therefore, bite any vertebrate it may come across in order to obtain the same.

The malarial parasites have, so far, only been found in man, and hence, until they are found in some other vertebrate, we are not justified in assuming that the Anophelines can obtain them from any other source. In the tropics the native population are undoubtedly the great source of the gametocytes by which the infection of the mosquito is brought about, because the majority of them do not protect themselves against mosquito-bites. Of the native population, the children are the greatest source of infection, because, as has already been explained, the adults obtain a partial immunity. But in considering the native as a source of infection, care must be taken not to forget the European, whose blood is sometimes swarming with gametocytes.

Ross has pointed out that, in considering the amount of malaria in a particular locality, imported cases must be distinguished from indigenous cases, and that the latter should be further classified according to the month in which they are infected. He has further attempted, by mathematical formulæ, to investigate the infection-rate of the disease, which method he terms ‘pathometry’; but it is very difficult to obtain the necessary data for these calculations. He points out that the number of infections in a given locality during a given period depend upon—

1. The number of persons with gametocytes in the blood.
2. The number of Anophelines which have bitten these people and become infected.
3. The number of infected Anophelines which live long enough to transmit the infection—*i.e.*, at least a week.
4. The number of these surviving infected Anophelines which get the chance of biting man again.

It is by no means easy to determine, even approximately, in a district the number of Anophelines capable of carrying malaria; but an attempt might be made to follow Ross, and determine the output from one or two of the more important breeding-places by enclosing a given area with mosquito-netting, and counting daily the numbers of Anophelines which hatch out. A calculation of the areas of the breeding-places, together with the numbers hatching per diem, will give a rough estimate of the increase during that time. Associated with this, a census may be taken of the Anophelines found inside damaged mosquito-curtains very early in the morning. This is a method we have used in West Africa and found of service, for it supplies not merely the number of the Anophelines, but also the percentage which are infected, though of course the error is likely to be considerable. Ross proceeds to show mathematically that the increase or diminution of the malaria really depends upon the ratio of Anophelines capable of carrying the parasite to the population; and, also, how an epidemic gradually increases, and how it diminishes, when the Anophelines are reduced; and proves that, in order that there may be a reduction of the malaria in man, there need only be a reduction in the numbers, and not an extermination of the Anophelines, which is what would appear to have happened in England, and to be the cause of the disappearance of malaria therein.

INVESTIGATION OF AN ENDEMIC REGION.—In investigating malaria in an endemic region, it is necessary to find out—

1. The specific diagnosis of the parasite or parasites causing the malaria.
2. The population of the area.
3. The average number of infected persons.
4. The average number of infected persons carrying the gametocytes in their blood.
5. The species of Anophelinæ in the district, and their breeding-grounds.
6. The species which carry the parasite.
7. The species in which the parasite is found in nature.
8. The number of Anophelines in the affected area.

No remarks need be offered with regard to 1, 2, 4, 5, 6, and 7.

With regard to 8, the method suggested by Ross should be adopted; and as regards 3, the quickest and the best method is to estimate the spleen-rate.

Ross suggests that the term 'endemic index,' which was introduced by Stephens and Christophers to denote the percentage of persons carrying parasites in their blood, should be extended to include not merely that factor, but also the proportion of people with spleens enlarged by malaria.

He therefore proposes that the endemic index should be made up of a parasite-rate and a spleen-rate, of which the latter is the more convenient, and if applied to children under fifteen years of age, is useful, provided that kala-azar does not occur in the locality investigated. Children are chosen because the adults have acquired a partial immunity, as already explained.

But the endemic index as defined by Ross is sure to be higher than the mere spleen-rate, and therefore the blood must be examined in the children whose spleens are not enlarged, and the parasite-rate must be added to the spleen-rate to obtain the true endemic index.

In all calculations such as the above, the statistical error must be borne in mind, and Poisson's formula, or the modification by Pearson which Ross recommends, must be applied.

Let $N =$ total number of children under fifteen years of age in a locality.
$n =$ number examined for spleen-rate.
$x =$ number with enlarged spleen.
$\frac{x}{n} 100 =$ spleen-rate.
$e\,\% =$ percentage of error.

Then by the Poisson-Pearson formula the percentage error will be

$$e\,\% = \frac{200}{n} \sqrt{\frac{2x(n-x)}{n}} \sqrt{1 - \frac{n-1}{N-1}}$$

PREDISPOSING CAUSES.—The causes which predispose to the disease may be classified into:

1. Those which promote infection with the parasite.
2. Those which promote the increase of the parasite in man after its inoculation.

1. THOSE WHICH PROMOTE INFECTION WITH THE PARASITE.—The first of these is residence in an area which contains not merely persons with gametocytes in their blood, but also mosquitoes capable of carrying the disease, associated with an atmospheric temperature suitable for the development of the parasite in the mosquito.

The second is any cause which produces large numbers of mosquitoes capable of spreading the disease. This will be not merely a suitable air-temperature, but also moisture. Hence low-lying, marshy places, and the wet season are important predisposing causes.

The third is occupation, for this may compel people to live in malarial countries, to reside in the low-lying marshy portions of the same, to work in rice-fields covered with water, etc. Age is a predisposing factor, as mosquitoes have more opportunity of biting a young child than an adult. Sex has no influence.

2. THOSE WHICH PROMOTE THE INCREASE OF THE PARASITE AFTER ITS INOCULATION.—These predisposing causes are subdivisible into: (*a*) racial; (*b*) personal; (*c*) meteorological.

(*a*) *Racial.*—There is no doubt that the native races suffer less than an immigrant race in a tropical country, where there is always malaria present, and this we believe to be mainly due to the acquired partial immunity of the native race, as already explained.

(*b*) *Personal.*—It will be obvious from the above remarks that the parasite cannot produce the markedly deleterious effects which we term malarial fever, unless there be a sufficiently large number present. Further, there appears to be a tendency on the part of the body to manufacture protective substances, which keep the growth of the parasite in check. Anything, therefore, which interferes with the production of these checking materials will enable the parasite to grow and multiply, and will thus become a predisposing cause of the disease. Such conditions are: (1) chills; (2) starvation or overfeeding; (3) the onset of another acute disease; (4) the presence of some chronic ailment, which may often be but slight.

(*c*) *Meteorological.*—We have already drawn attention to the relationship between the temperature of the external air and the development of the parasites in the mosquito. It now remains to point out that a similar relationship exists between that condition and the development of the parasite in the human being.

Ross is of the opinion, not merely from observations upon man infected with malaria, but also upon birds infected with *Halteridium*, that high air-temperatures are favourable to the increase of the malarial parasites in man. High air-temperatures are therefore a cause of the relapses met with so frequently in the hot dry season of the tropics.

The reverse is also true; hence the benefit of sanatoria at high altitudes in the tropics, and also of sending a fever-stricken patient to cooler climates, provided the change from the hot to the cold climate be not sudden, but gradual.

Climatology.—The geographical distribution of malaria is determined by a combination of the conditions suitable for the production of large numbers of mosquitoes capable of carrying the germ, with those suitable for the development of the parasites in the mosquitoes, together with the presence of human beings with numbers of gametocytes in their blood.

The virulence in one region more than in another may depend upon the type of parasite. Thus, *Laverania malariæ*, which is a more virulent parasite than *Plasmodium malariæ* or *P. vivax*, being very common on the West Coast of Africa, renders that area peculiarly dangerous.

Generally speaking, malaria is most prevalent in the region of the Equator, and diminishes gradually north and south till the Arctic and probably Antarctic Circles are reached. The malarial area lies between 63° north latitude (mean summer isotherm of 15° to 16° C.) and 35° south latitude. Its geography may alter considerably in the course of years. Thus regions in England, Holland, France, Germany, and Austria-Hungary are much less malarial than they formerly were. On the other hand, it has been known to affect countries which at one time were immune. Thus Ross says that he believes that Mauritius was infected in the early sixties of last century by the introduction of a mosquito capable of spreading the disease, and hence the epidemic which occurred in that island. Réunion is another example. Therefore the geography to be described is that known to exist at present.

Africa.—The worst malarial region in the world is probably the West Coast of Africa, from Senegal to the Congo, but the whole of Africa, except portions of Cape Colony, is malarial.

Asia.—Malaria is widespread throughout Asia, being very marked in certain districts of India, especially the swampy land at the foot of the Himalayas, and in Ceylon; while Arabia, Syria, the Straits, Siam, and China are also malarial. Little is known about Siberia.

Australasia and Polynesia.—Most of Australasia except West Australia is free from malaria, but it occurs in New Guinea, Finschafen, the Solomon Islands, and the Bismarck Archipelago.

America.—Malaria exists in Central America, the West Indies, the coast of the Mexican Gulf, the north of South America, including British Guiana, and the north of Brazil as far as Rio de Janeiro. Paraguay and Bolivia are infected, as are Peru and Chili, but the south part of South America is less infected. Many places in the United States are malarial, but Canada is not markedly infected, except about the northern shore of Lake Ontario, while Greenland is supposed to be free.

Europe.—Great Britain and Norway are practically free, but most of the other countries have endemic foci, particularly Russia, Italy, Greece, Turkey, and Austria-Hungary.

In France malaria exists in the south and west; in Switzerland in the canton of Tessin; in Germany along the course of the Rhine, and in the lowlands watered by the tributaries of the Danube. Sweden has also some endemic spots.

Apart, however, from mere geographical distribution, it will be obvious that the necessary conditions for malarial propagation are best supplied in the tropics, especially near the Equator, where there is generally a considerable amount of atmospheric moisture and rain as well as heat.

The wet season has also a great influence, supplying the necessary moisture which at other times may be lacking. The effect of altitude has already been mentioned.

Pathology.—In malaria the body is invaded by protozoal parasites, which grow and increase at the expense of the red cells of the blood, and in doing so, manufacture toxins, of which we know two—viz., a pyrogenetic toxin and a hæmolysin.

Red blood cells are found in the whole of the circulatory organs but are generally contained in arteries, veins, and capillaries. In two places, however—viz., the spleen and bone-marrow—they come intimately into relationship with the parenchyma cells. Whatever function the spleen may in future be found to possess, as regards the malarial parasites, it probably acts as a purifier to the blood which passes through it. Perhaps the bone-marrow assists in such a function.

Parasites contained in red cells should, therefore, be able to pass all over the body, and should be found equally distributed, no matter what organ is examined. This would be so if the parasite did not seriously damage the red cell, and, by its toxins, the endothelium of the vessels, especially that of the capillaries, in which the blood-flow is slowest. It would appear as though the damage done to the red cell by the quartan parasites is not severe enough to cause them to be caught in the capillaries. Therefore the whole life-history of the quartan is spent in the circulation, and sporulating forms can be readily seen in finger-blood.

Tertian parasites, on the other hand, seriously affect the red cells causing swelling, degeneration, and decolorization. The trophozoite and schizont stages are easily seen in the peripheral circulation Still, the sporulating forms are more common in the spleen, which may be looked upon as having filtered them off from the blood which passes through it.

The subtertian parasites act deleteriously on the corpuscles making them smaller and darker. They rarely appear in the peripheral circulation in the sporulating condition, while they abound in the spleen and internal organs. On examining the organs post-mortem, it will be found that the schizont and sporulating forms are found in the capillaries, while the trophozoites are found attached to the walls of the arterioles and venules.

The sporulating parasites give rise to hæmozoin, which escapes from the corpuscle along with the merozoites, and will therefore be most commonly found in those tissues and organs in which sporulation takes place—*e.g.*, spleen, liver, and bone-marrow—and will give them a definite coloration, varying from a reddish-brown to black, according to the quantity present.

This pigment will, of course, be also met with in the periphera blood, both free and inside mononuclear leucocytes, for, on escaping from the parasite, the hæmozoin is seized by the mononuclear leucocytes, macrophages, and the endothelial cells of capillaries therefore, in acute malaria, it will be distributed evenly through the organ affected. The pigment is later conveyed from the blood vessels into the tissues by the phagocytes, and is found in the connective tissue of the organ close to the bloodvessels. Eventually i disappears, being partially digested by the phagocytes and tissue cells, and partially removed by the lymph. This process, however cannot continue without causing irritation of the connective tissue

Not merely does pigment escape from the sporulating parasite but also hæmolysin, which damages the red cells, and causes the appearance of another pigment, yellowish in colour, called 'hæmosiderin.' This is deposited in the parenchyma cells of the organs—*e.g.*, the liver—and may perhaps damage them.

Another toxin—this time pyrogenous—also escapes from the sporulating parasite, and may be the cause of the hyperæmia found in the internal organs—*e.g.*, the spleen and the liver in acute malaria—and may also cause the destruction of the parenchyma cells of those organs. After a series of attacks the blood capillaries and lymph spaces in the liver and spleen remain permanently dilated, and separated by only a slight amount of damaged parenchyma tissue. Later, regeneration of the parenchyma takes place, but the organ will remain permanently altered, even though all pigmentation may have disappeared.

In the case of the subtertian parasite, serious local damage may be caused to the brain, the intestine, the pancreas, or other organs by the parasites massing in the capillaries and forming, with free pigment and swollen endothelial cells laden with pigment and parasites, regular thrombi, sufficient to impede the circulation, and thus to still further damage the toxin-poisoned organ. Finally, the toxins are excreted by the skin and by the kidney, and in doing so may damage the latter organ.

There are two main conditions, the pathology of which must be explained—viz., acute and chronic malaria. In acute malaria there are the effects produced by each of the three parasites, of which the subtertian is liable to seriously damage important organs.

Chronic malaria should also be described according to the three types, but there is at present lack of material to evolve such a description. Chronic malaria may, however, pass to an advanced condition called 'malarial cachexia,' which shows itself in three ways—as (1) a rare acute cachexia ; (2) a more common chronic cachexia ; (3) cachexia with amyloidosis.

In addition, there are the pathological features of latent malaria and the relapses to be discussed.

Before, however, proceeding to describe the actual morbid anatomy of these conditions, a few words must be said upon wha we know of the chemical pathology of the disease and on the bloo changes which take place.

Chemical Pathology.—The pyretogenous toxin has already bee mentioned among the poisons of animal origin, and, though lon suspected of being present, its actual occurrence was first prove by Rosenau and his collaborators. Probably it is the poison whic acts deleteriously upon the tissues of the organs and causes metabolic changes, but this is only a matter of conjecture.

We know that the heat output in the cold stage of the attack i markedly diminished—a condition met with in many fevers—bu the chemistry of the metabolic changes is but little known. Durin the attack the urine is at first increased in quantity, which is though to be due to the rise of blood-pressure internally, owing to th contraction of the cutaneous vessels during the cold stage. Notwithstanding this increase in quantity, the specific gravity is raised because of the increased metabolism caused by the toxins, as i shown by the large increase in solids. The colour is dark, and th acidity of the urine is increased, as in most fevers. Nitrogen i excreted in excess, which is largely due to the increase of urea Chlorides, sulphates, and bases, especially potassium, are all increased in quantity. Phosphates, however, are diminished durin the actual attack, but increased as it is passing off, and are considerably increased in the intermission. Phosphoric acid is therefore retained in the body during the attack.

As would be expected, iron is excreted in increased quantity probably due to hæmozoin and hæmosiderin, but this increase doe not really appear until after the actual attack is over, and the continues for some days.

As before remarked, the urine may contain a considerable quantit of urobilin, and the indigo-blue may be also increased. The diazo reaction is said to be obtainable in about 5·5 per cent. of cases Serum-albumin may be present after severe attacks, and proteos has been reported, as well as nucleo-proteid.

When the intermission comes, the urine diminishes in quantity but nitrogen is still excreted at a higher rate than it should be, though less than during the attack.

Chlorides are diminished, phosphates increased; sulphates, though still higher than normal, are less than during the attack, while the excretion of the bases is diminished. The excretion o iron is marked, and the toxicity of the urine is said to be considerable.

During convalescence the most marked features are the polyuria, with low specific gravity, which in subtertian fevers may be so marked as to alarm the patient, while in quartan and tertian it may be so slight as to escape attention. There is also increase of chlorides and potassium salts excreted.

As regards the fæces, the most noticeable feature is the increase in the excretion of bile and iron, both of which are related to the blood-destruction.

The sweat of a malarial patient is well known to have a peculiar odour, and contains substances very toxic to rabbits.

The above chemical features point to the fact that the toxins of malaria are excreted from the body by the sweat and the urine, and that during the fever there is very active nitrogenous, potassic, chloride, and sulphate metabolism.

That there may be other toxins as yet unknown is obvious from the fact that the *Plasmodia* cause marked shivering and a sensation of coldness, even though the actual blood temperature is rising. It would appear as though this is due to the constriction of the cutaneous vessels by some poison which acts on non-striped muscle, for the arrectores pilorum are also affected, producing goose-skin. *Laverania malariæ*, however, because it sporulates internally, and not in the peripheral blood, causes chills more rarely than the other two.

De Blasi has shown that an antihæmolysin is formed in the human body, and Casagrandi, as already mentioned, has performed experiments on *Halteridium* in birds, tending to show that this substance has a restraining power against increase of the parasites.

The only other remarks we can offer on the chemical pathology are limited to the nature of the pigments, hæmozoin, and hæmosiderin.

HÆMOZOIN.—Hæmozoin is the black pigment formed from hæmoglobin by the malarial parasites while living in the erythrocytes, and is afterwards distributed over the body on the disruption of the red cells. It is taken up by phagocytes, as already described, and removed from the bloodvessels to the connective tissue, in which it can be seen in the liver and spleen. It is soluble in alkalis, but not in water, alcohol, chloroform, ether, or acids. It contains iron, but in the form of an organic compound, which will not give the Berlin-blue reaction. Eventually it disappears from the connective-tissue cells, but whether it is eliminated from the body or used in some altered form we do not know. As it is formed by malarial parasites, it is peculiar to the diseases caused by them.

HÆMOSIDERIN.—This is the yellow pigment found in the form of yellow granules in the parenchyma cells of the liver, spleen, kidney, bone-marrow, endothelium of capillaries, and occasionally in leucocytes, after any great destruction of blood cells. In malaria it is undoubtedly due to the action of hæmolysins destroying the red cells. It contains iron in the form of an inorganic compound, and gives the usual Berlin-blue reaction. It is insoluble in alkalis and acids, but is soluble in alcohol.

The Blood.—The parasites live in the blood, in which they produce changes by their own action and by that of their toxins.

The malarial parasites, being true blood parasites and living in the red cells, form the most important feature of the pathology of the blood, but their structure and life-history having already been described in the chapter on Protozoa (p. 289), it only remains to estimate their numbers.

Ross estimates that a medium-sized person of 68 kilogrammes (150 pounds) body-weight possesses 25,000,000,000,000 erythrocytes. In a severe infection he estimated the parasites as numbering 12 per cent. of the corpuscles—*i.e.*, 3,000,000,000,000—and, further, he considers that if they fall below 1 to 100,000 corpuscles—*i.e.*, 250,000,000—they will cause but little disease. Certainly, large numbers of parasites can exist in the body and go through their life-cycle in the spleen without causing symptoms. This condition is called 'latent malaria,' and can be easily converted into active malaria by any cause which depresses the vitality of the body.

ERYTHROCYTES.—In quartan malaria the corpuscle containing the parasite is a little smaller than a normal corpuscle, and, if anything, more darkly coloured. In tertian malaria it is swollen and more lightly coloured, and on colouring with Leishman's stain exhibits fine red granules (Schüffner's dots), which are to be looked upon as a sign of degeneration of the corpuscle. In subtertian malaria the corpuscles when stained by Leishman may exhibit Maurer's dots or clefts, which appear as large, irregular red formations, the significance of which is uncertain, and in addition the red cells become transformed into brassy bodies, which are red corpuscles which have become shrunken and taken on the colour of brass. These are corpuscles which have undergone some form of necrosis, probably due to the hæmolysin, though it has been thought that they were infected corpuscles in which the parasite had died as a result of the necrosis.

Partial decolorization of the erythrocytes has been recorded in subtertian infections, and is especially well marked in those containing crescent bodies. Bignami thinks that in the subtertian fever the red corpuscles, which are infected with the parasite, have a diminished elasticity, and therefore are not so capable of circulating, and cling to the walls of small capillaries.

As every sporulation causes the destruction of red cells, anæmia is one of the marked features of malaria. This destruction takes place at each paroxysm, and though in quartan and tertian fever it may be slight, in subtertian fever it is apt to be considerable. Thus in twelve hours during a subtertian attack Dionisi notes a fall from 4,500,000 to 4,000,000 erythrocytes, while in pernicious fevers the loss may be even greater.

After a certain number of attacks of fever the loss becomes much less than in the earlier seizures.

When the fever is intermittent regeneration takes place quickly, so that before the next paroxysm the normal number of erythrocytes may be nearly reached; but even in quartan and tertian fevers, if long-continued, anæmia will result.

The histological changes in the unaffected corpuscles are pallor and poikilocytosis, and in severe cases megaloblasts, with polychromatophilia and basic granular degeneration, together with normoblasts, may be noted. The tonicity of the corpuscles is increased after a number of attacks, according to Viola. In the blood of malarial cachectics the brothers Sergent have described basophile formations having the shape of a figure 8, with a double contour, and Brumpt and others have described basophile rings with a single contour. Laveran considers these appearances to be due to artefarcts.

LEUCOCYTES.—The leucocytes are at first increased during the paroxysm, and then markedly diminished, so that a leucopenia is the characteristic of the simple malarial fevers. The normal ratio of white to red corpuscles is 1 to 500 or 600. From observations of Stephens and Christophers this may be 1 to 90, 1 to 200, 1 to 290, or 1 to 300 during the rigor (*i.e.*, leucocytosis), becoming 1 to 764 (*i.e.*, leucopenia) when the rigor was completed, and when the temperature fell altering to 1 to 968. Billet has shown that if curves are made of the leucocytic count and the temperature in simple tertian and quartan fevers, the two curves follow one another in their rises and falls. In pernicious malaria there may be leucocytosis.

Another important matter is the relative increase of the large mononuclear leucocytes, and this is better marked during the leucopenia of apyrexia than during the leucocytosis of the attack.

The following are some examples of the differential count according to various observers :

Kind of Corpuscles.	Da Costa.	Billings.	Christophers and Stephens.	Bastianella.
Polymorphonuclears ..	67·00	65·04	50·2	39·0
Large mononuclear and transitional	15·94	16·90	31·4	41·0
Lymphocytes	15·33	16·90	18·1	19·1
Eosinophiles	00·83	00·96	00·4	00·6

It must be remembered that this relative increase in the mononuclears has been noted in other protozoan infections.

Phagocytosis is particularly seen in the large mononuclear and transitional leucocytes, and to a less degree in the polymorphonuclear leucocytes and very rarely in the eosinophiles. In these cells clumps of pigment and the residue left after segmentation of a schizont are not uncommonly seen. If, however, something abnormal takes place in the red corpuscle, a phagocyte may engulf it and its parasite, or only the parasites if they have escaped from the red cell, or only the débris of the red cell.

Vacuolization and diminution of the staining power of leucocytes are to be seen. Myelocytes are said by Da Costa to be found in subtertian infection up to 0 51 per cent. Eosinophiles diminish during the paroxysm, and increase during the apyrexia.

HÆMOGLOBIN.—This is, of course, reduced, but the colour index may vary sometimes, being less than normal.

THE SPECIFIC GRAVITY OF THE BLOOD.—Diminution of the density of the blood begins at the onset of the attack, and becomes more marked as it proceeds, and may amount to a diminution of 6·2 degrees. This fall is probably due to destruction of red cells and the breaking up of large parasites, which more than balances any loss of liquid by vomiting, diarrhœa, sweating, and polyuria.

The diminution is most marked in full-blooded persons, in primary affections, and first attacks, less in later attacks, and least in chronic malaria. The density recovers after treatment by quinine.

CHRONIC MALARIA.—In chronic malaria there is a leucopenia and a marked decrease in the numbers of the red cells, which is but little affected by febrile attacks.

POST-MALARIAL ANÆMIA.—Bignami points out that there are cases in which, in spite of the cessation of the malarial fever, the anæmia tends to progress, and these he calls post-malarial anæmias. They are generally induced by age, malnutrition, overwork, pregnancy, nursing, etc., and are not due merely to the malarial infection. Bignami divides these into four types, according to the characters of the blood.

First Type.—This form of anæmia comes on after attacks of ordinary acute malaria, and is characterized by well-marked diminution in the erythrocytes, the presence of normoblasts, diminution of the colour-index, and leucopenia associated with relative mononuclear increase. In this type the prognosis is good.

Second Type.—The second type is severe, and the prognosis is exceedingly bad. It is characterized by great diminution in the red cells, presence of poikilocytes, megalocytes, normoblasts, and megaloblasts, with leucopenia and relative mononuclear increase.

Third Type.—This is rapidly fatal, and has similar characters to the second type, but is without normoblasts.

Fourth Type.—This type is really grave chronic anæmia, resembling the first type, but being specially characterized by the paucity of the normoblasts and the marked leucopenia.

Morbid Anatomy.—The morbid anatomy of malaria has been most carefully studied in recent years by Bignami in Italy and Ewing in America. It may be considered under the following headings:

A. ACUTE MALARIA.

1. Lesions caused by *Plasmodium malariæ.*
2. Lesions caused by *Plasmodium vivax.*
3. Lesions caused by *Laverania malariæ.*

B. CHRONIC MALARIA.

1. Lesions caused by *Plasmodium vivax.*
2. Lesions caused by *Laverania malariæ.*
3. Malarial cachexia.
4. Latent malaria.

A. MORBID ANATOMY OF ACUTE MALARIA—1. LESIONS PRODUCED BY PLASMODIUM MALARIÆ.—*Plasmodium malariæ* goes through the entire process of schizogony in the circulating blood, and hence is evenly distributed all over the body, and therefore does not especially accumulate in any one organ. Marchiafava and Bignami mention that they have made two autopsies, one on a case of acute quartan malaria, in which the patient died of nephritis, and the other in a case of the same fever, in which the patient died of spinal disease. All they noted with regard to the visceral lesions were: *Spleen* enlarged, not softened nor very melanotic; *liver* and *bone-marrow* not markedly melanotic; *parasites* in the spleen and in the blood, but not in the brain.

Colonel Sir W. Leishman has mentioned that he has received films from the peripheral blood and spleen of a fatal case, in both of which the parasites were very numerous, but he was not in a position to state whether the patient died of malaria or not. If *P. malariæ* is to produce severe symptoms, it would appear necessary for it to exist in very large numbers.

2. LESIONS PRODUCED BY PLASMODIUM VIVAX.—It is rare for death to ensue as the result of an infection with *P. vivax.* Still, this does occur at times when there is a heavy infection. Ewing has described a case of tertian infection causing coma, hæmoglobinuria, and either causing or associated with catarrhal colitis, the principal features being the pigmentation of the bone-marrow, liver, and spleen, which last was also enlarged. The blood and spleen showed large numbers of *P. vivax.* The kidneys and colon were inflamed, and the endothelial cells of the brain were swollen and contained pigment.

3. LESIONS PRODUCED BY LAVERANIA MALARIÆ. — We have already insisted several times upon the fact that *L. malariæ* differs from the other malarial parasites in sporulating in the organs, generally in the spleen, but at times choosing one organ and at other times another. The organ in which it sporulates in large numbers suffers most, and produces symptoms which give the characters of that particular type of malarial fever.

Thus the parasite may attack principally the brain, the intestine, the heart, or the pancreas, producing marked signs of disease therein. Therefore the conditions of the organs vary with the localization of the parasite.

In general the body is pale, with a yellowish tinge, which may be noted superficially in white races, but which may only be observed in the subcutaneous tissues in native races. The heart may be small or dilated, the muscle flabby and pale, and ecchymoses may be present in both the epicardium and endocardium. The lungs may be normal, anæmic, or hyperæmic and congested. Hæmozoin is not easily detected in the lungs because of the usual pigmentation. As first described by Laveran, a sclerosis of the lungs is not infrequently met with.

The liver is generally enlarged, and varies from a dark brown to a slate colour. It is soft and congested, and the outlines of the lobules are usually indistinct. The gall-bladder is full of dark-coloured bile.

The spleen is enlarged, with a tense capsule, but its consistency is much less than normal, and at times it may be almost diffluent in very acute cases. Its colour varies from a deep brown to a black.

The stomach and intestines may show but little change, except in the choleraic forms, in which their mucosa may be intensely congested and dark red in colour, except where the Peyer's patches and the solitary glands stand out clearly. The intestine is darker red in certain places, giving it a mottled appearance, and the contents may be blood-stained fluid with flakes of mucus. In fact, the appearance post-mortem and the history, if death takes place rapidly, so much resemble those of cholera that in regions where that disease is prevalent mistakes may arise, though, indeed, the dark pigmentation should enable errors to be avoided. We have not infrequently met with dark pigmentation of the small and large bowels in cases of pernicious cerebral malaria. This pigmentation is due to hæmozoin, as can be easily proved by microscopical examination.

The lymphatic glands may be swollen, while the pancreas is usually normal, but it may be very rarely swollen and hæmorrhagic—*i.e.*, in a condition of hæmorrhagic pancreatitis.

The suprarenal capsules may be congested. The kidneys are more or less normal, but sometimes they are congested, with punctiform hæmorrhages in the pelvis and cloudy swelling in the parenchyma. The serous membranes, pleura, and peritoneum, show as a rule nothing remarkable, except, perhaps, a little pigmentation. The bone-marrow is generally hyperæmic and chocolate-brown in colour. The brain may appear normal, but in the cerebral type of pernicious malarial fevers there will be marked changes. In slight cases there may be only œdema without pigmentation or petechiæ. Sometimes there is brownish pigmentation without petechiæ, and with or without œdema. Typically, however, there are: (1) Hyperæmia of the leptomeninges which may be œdematous and thickened; (2) brownish, or even blackish, pigmentation of the cortex; and (3) punctiform hæmorrhages in the white matter under the cortex or elsewhere. The spinal cord exhibits changes similar to those in the brain, while the retina show numerous hæmorrhages.

Microscopical Examination.—After death, parasites may be found in the blood of the heart, spleen, bone-marrow, and at times in the capillaries of the brain, intestines, pancreas, etc.

The parasite, however, is much shrunken, and the typical forms seen during life are not distinct after death. Thus the ring form shrinks and becomes a rounded disc, with the chromatin particle situated at the periphery. The fully developed schizont is more typical, the merozoites being arranged in a ring around the central pigment block. The mononuclear leucocytes will be noted to have pigment granules, while the polymorphonuclears may show phagocytosis. In films from the internal organs macrophages with parasites and red cells may be seen.

In the heart there may be a few parasites, but very rarely the capillaries will be found filled with red cells containing numerous parasites, and the heart muscle laden with hæmosiderin, as has been described in a pernicious cardiac form of malaria.

The lungs may contain parasites in all stages of their existence, as well as pigmented macrophages, and leucocytes. It is, perhaps, doubtful whether there is a true form of malarial pneumonia. Bignami has stated that the pneumococcus is always present, and that a pneumonia in a malarial patient is a double infection.

The capillaries of the liver are much enlarged, with swollen endothelial cells often laden with pigment. These capillaries are filled with blood cells containing parasites and leucocytes with pigment. The perivascular lymph-spaces are swollen, and Küpfer's cells contain pigment. The liver cells are compressed between the dilated capillaries, and contain hæmosiderin and bile-pigment, and, in addition, isolated cells or groups of cells may be necrosed, but this is rarely extensive. The portal canals are infiltrated with red cells, containing parasites in all stages of development.

In the spleen the red cells of the pulp are seen to be filled with schizonts and crescents, while pigment is present in leucocytes and macrophages. The kidneys show pigmentation in the walls of the capillaries of the glomeruli, as well as those lying between the tubules; but parasites are rare in the former, though common in the latter situation. Phagocytes are not uncommon containing pigment, red cells, and parasites. The cells of the glomeruli degenerate, and are thrown off into the capsule along with exudation, and the epithelial cells of the convoluted tubules degenerate, and are cast off into the lumen.

The suprarenal capsule shows irregular areas of vascular dilatation full of erythrocytes, many of which contain parasites, while macrophages may also be present.

The capillaries of the abdominal fat are often full of red cells containing parasites. The bone-marrow is chocolate-coloured in the small bones, and brownish-red in the long bones. Often it is soft and diffluent, and contains sporulating parasites and, in particular, crescents (gametocytes), which are thought to start their life here.

When the intestine shows the choleraic appearances described above, the capillaries of the mucosa and villi are filled with parasites in all stages of schizogony, and leucocytes with pigment masses. The epithelial cells are necrotic, but the submucosa and deeper layers escape injury, and their blood-vessels contain nearly normal cells.

The brain in pernicious cerebral fevers has its capillaries filled with sporulating parasites, while the arterioles and venules are freer, and only contain young forms. Sometimes no parasites are to be seen, and only pigment in the endothelial cells, which may be swollen and fatty. The nerve cells may be affected, showing damage to or disappearance of Nissl's bodies, and degeneration of their nuclei. The punctiform hæmorrhages are due to the diapedesis of apparently normal red cells.

B. MORBID ANATOMY OF CHRONIC MALARIA.—The lesions of chronic malaria fall principally upon the spleen, the liver, and the bone-marrow. We are not acquainted with any records of post-mortems on persons suffering from chronic malaria due to *Plasmodium malariæ*.

1. LESIONS DUE TO PLASMODIUM VIVAX.—The best recorded case of this infection is that given by Ewing of a man who suffered from the disease for about a year, and died from endocarditis about three months after the last attack. The spleen was enlarged, firm and dark, and contained parasites and pigment in endothelial cells about the Malpighian bodies. Some hæmosiderin could also be seen. The liver showed no gross signs indicating malaria, but, microscopically, pigment was collected in large intracellular masses in the portal canals and slightly in a few endothelial cells throughout the lobule. Macrophages also contained pigment. The marrow was but slightly pigmented, showing a few endothelial cells with black pigment.

2. CHRONIC MALARIA WITHOUT DEFINITION OF THE PARASITE.—These lesions are generally due to *Laverania malariæ*, and, as stated above, affect the spleen, liver, and bone-marrow.

The spleen is always enlarged, often considerably, and is firm in consistence, but its colour varies from a slate to a dark red, which depends upon the amount of pigment deposited therein. Usually there are some adhesions indicating old perisplenitis. On section it generally appears quite black, but this depends upon the amount of pigment; the capsule is thickened; the Malpighian follicles stand out clearly, as they are enlarged and non-pigmented. Microscopically the capillary vessels are seen dilated and separated by splenic pulp, or by connective tissue containing giant cells. The pigment may be diffused through the organ, but is generally either collected around the follicles or extracellular, and contained in the lymphatics of the arterioles or septa, both of which are thickened.

The liver is larger and harder than usual. If pigment is present, it will usually be gathered around the periphery of the lobules, which will, therefore, stand out clearly. Later the pigment becomes perivascular, and finally disappears. The capillaries or lymph-spaces may be considerably dilated, and the liver cells atrophied by pressure. On the other hand, proliferation of the hepatic cells and repair of the damage may be seen taking place. Atrophy of the liver is not usual, but may occur in old people from thrombosis of the portal vein, and is then associated with necrosis.

The bone-marrow is usually pigmented, and of a chocolate hue in the small bones, while in the long bones it may be reddish, except, perhaps, in the very centre. This colour is due to the replacement of the fat by vascular tissue.

3. MALARIAL CACHEXIA.—This may be acute when it develops after a few attacks of fever, but more commonly it comes on as a sequela to chronic malaria. The anæmia is marked, and there is fluid about the ankles and in the abdominal cavity. The spleen is enormously enlarged, as is also the liver, while the bone-marrow is yellow, sclerotic, or gelatinous. Parasites may be found, or they may be absent.

A special form of cachexia is that in which amyloid changes are found in the kidney along with parenchymatous nephritis, associated more rarely with amyloid changes in the intestine, spleen, and liver, with sometimes simple ulceration of the intestine.

4. LATENT MALARIA.—*Plasmodium vivax* and *Laverania malariæ* can exist in the spleen of persons who show no sign of fever or malarial cachexia. These parasites can go through their life-cycle in that organ, and in the case of *L. malariæ* in the liver also, but it would appear that they are restrained from invading the circulation by the action of some antitoxin, and therefore do not increase to such numbers as to cause toxic symptoms.

Relapses.—It is obvious from the above that, if the restraining influences which conduce to the condition of latent malaria are removed, an attack of malaria will follow, or if there has been a previous attack, a relapse will take place.

Observers have always had a difficulty in admitting that the ordinary form could be latent and cause a relapse, though there appears no doubt that this can take place. Schaudinn, as has already been mentioned, considers that the macrogametocyte is capable of undergoing parthenogenesis and forming merozoites, thus starting a cycle of schizogony anew and causing fever. Craig and other observers insist upon conjugation, causing a rejuvenescence of the parasite and a relapse of the fever.

THE CLINICAL DESCRIPTION OF MALARIAL FEVERS.

ACUTE MALARIA.

As there are three parasites—*Plasmodium malariæ*, *P. vivax*, and *Laverania malariæ*—there are therefore three clinical entities—quartan malarial fever, tertian malarial fever, and subtertian malarial fever—due to these parasites.

Quartan and tertian parasites go through their whole life-history in the circulating blood, and though the tertian sporulating forms are found in internal organs, such as the spleen, yet they do not tend to accumulate in those organs or to produce special effects. On the other hand, the subtertian parasite sporulates entirely, or almost entirely, in the internal organs ; and if one particular organ is especially attacked by the parasites, there will be special clinical features to that phase of the disease, which have for many years been alluded to as the perniciousness of this type of fever, and these pernicious symptoms will depend upon whether the parasite is principally localized in—(1) the cerebro-spinal nervous system ; (2) the gastro-intestinal mucosa ; (3) the pancreas ; (4) the heart ; (5) the lungs ; (6) the liver.

THE QUARTAN FEVERS.

Quartan malarial fever depends for its symptoms and course upon the life-history of *Plasmodium malariæ*, introduced into the blood of man by an Anopheline mosquito. Its clinical course will depend entirely upon whether the parasites are of approximately the same age, or whether they have been introduced into the body on different days.

If only parasites of approximately one age exist in the blood, a typical quartan malarial fever ensues, with an interval of seventy-two hours (the length of time which a merozoite takes to become the fully developed schizont). Such a fever is called ‘ quartana simplex,’ or simple quartan fever.

If the parasites have been introduced on two different days, and are therefore of different ages, the patient will develop fever on two successive days, and be free from it on the third day ; such a fever would be called ‘ quartana duplex,’ or double quartan fever.

If, however, the parasites were introduced on three successive days, the fever may be daily—that is to say, may be a quotidian fever—and this could only be recognized as belonging to the quartan fevers by its parasite being discovered microscopically ; such a fever would be called a ‘ quartana triplex,’ or triple quartan fever.

Simple Quartan Fever.

Incubation.—This has not been determined with any degree of certainty. It is without doubt longer than either tertian or subtertian. Celli, by experiment, came to the conclusion that it might be very long—two months or more.

By the experimental inoculation of blood, Marchiafava and Bignami calculated the maximum incubation at 18 days, the minimum at 11 days, and the mean at 14·3 days. We are not aware of any experiment to determine the incubation period after the bite of infected mosquitoes.

The Febrile Attack.—Generally there are prodromata before an attack of quartan fever. Some few hours previously the patient may complain of giddiness, weakness, malaise, headache, or even nausea and vomiting. If the blood is examined during the occurrence of these symptoms, the parasites will be seen to be schizonts, and the commencing formation of merozoites may also be noted.

In a short time the definite attack begins. It may roughly be divided into three stages: (1) The cold stage; (2) the hot stage; (3) the sweating stage.

1. *The Cold Stage.*—The patient begins to feel cold, either in the legs, arms, or back. This sensation increases until actual shivering sets in. In quartan fever the rigors are well marked and characteristic, and the patient may shiver until he shakes the bed; the teeth may chatter, the lips become blue, the arms and legs cold, and goose-skin may be present. If the blood is examined in this stage, some of the parasites may be seen fully sporulated, or only young parasites may be found.

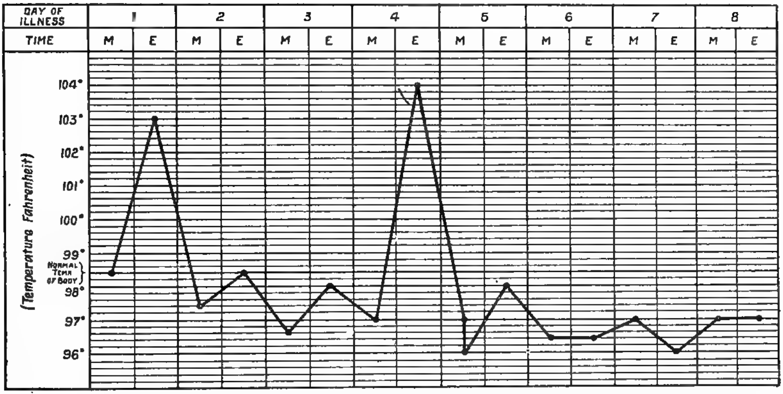

FIG. 293.—TEMPERATURE CHART OF A CASE OF SIMPLE QUARTAN MALARIAL FEVER IN THE GENERAL HOSPITAL, COLOMBO.

During this cold stage, which is the most uncomfortable of the three stages, the internal temperature is rising rapidly, and the internal organs must be somewhat congested during the chill; for there are symptoms of intense headache, visual disturbance, vomiting, and at times diarrhœa. The temperature, which rises before the chill begins, varies at first from 100·4° F. to 102·2° F., but generally rises rapidly to its maximum—about 104° F. or 105° F. The cold stage does not last long, fifteen to thirty minutes being the average time, but it may be longer or shorter, and may be irregular, being preceded by a transient sensation of heat.

2. *The Hot Stage.*—Gradually the shivering ceases, and the patient begins to feel warmer and more comfortable, though sensations of cold and heat may succeed one another. By degrees the sensation of heat increases, until the patient becomes burning hot, and as in the cold stage he desired to wrap himself up with coverings, now

he desires to throw these off. The skin feels hot and dry, the pulse and respirations increase, the conjunctivæ become injected. Vomiting and diarrhœa may take place, and an erythematous rash sometimes appears. The temperature reaches its maximum, and soon declines.

This stage may last about three to four or more hours.

3. *Sweating Stage.*—Towards the end of the hot stage the forehead is noticed to be damp, and presently the sweat begins to appear profusely, and great relief is felt by the patient. As the sweating increases, the temperature falls rapidly and the pulse-rate declines. As the temperature approaches normal the patient may fall into a sleep, from which he will wake feeling much better, and with a normal or subnormal temperature. The total duration of the attack may be about eight to ten hours.

The Interval.—After awaking from his sleep the patient feels quite well, though weak, and generally goes about his ordinary work during the two days of this interval. But signs are not wanting that everything is not well ; for the temperature is often subnormal and the pulse slow, while in the blood the developing parasites may be traced, and leucopenia with relative mononuclear increase noted. At the end of seventy-two hours the apyrexial interval will end in an attack of fever, as described above.

Irregularities.—Prolongation of the attack has been noticed. Marchiafava and Bignami state that it may very exceptionally last for more than twenty-four hours, in which case the temperature shows two chief undulations—one near the beginning and the other near the end of the attack—separated by a marked remission.

Children.—Children may show neither cold nor sweating stages. Very often convulsions take the place of the cold stage, but these may be so slight as not to be noticed. On the other hand, they may be very severe.

The Course of the Fever.—Quartan, rightly or wrongly, is believed to have a great tendency to relapse, to go on for months, and even, it is said, for years, if not treated. The parasites rarely appear to multiply to any great extent in the blood, and hence pernicious symptoms are usually absent. If left to itself, the fever is supposed to gradually die out, but to recur at times. Spontaneous cure is, however, rare.

Double Quartan Fever.

In this form there is an attack of fever on two successive days, and an apyrexial interval of twenty-four hours.

Typically the two attacks should be equal in severity, but often this is not so, for one attack is less severe than the other. As already stated, this may be due to two groups of parasites inoculated on separate days. But sometimes quartana simplex may become quartana duplex, and this is explained by the fact that there may be a double infection, but that while there are many of one brood of parasites, and hence fever, the other brood may be so few at first that they require time to develop to such numbers as are necessary for the production of fever. Consequently quartana duplex may at first show itself by a very slight rise in the temperature on the second day, which increases gradually till equal to that produced by the stronger infection.

Triple Quartan Fever.

This is a quotidian or daily fever produced by three broods of quartan parasites coming to maturity on three successive days, and can only be diagnosed by an examination of the blood. The three attacks may be similar, and may begin at the same hour, or they may vary in severity and begin at different times. In quartana triplex sometimes an attack may be 'subintrant'—that is to say, the cold stage of one attack may begin before the sweating stage of the other attack is finished; but this is not common, and usually there is a distinct interval of normal or subnormal temperature.

A simple or a double quartan may become a triple quartan in the manner described above for the origin of a double from a simple fever. On the other hand, it may start as quartana triplex, and become a duplex, and finally a simplex. This may be due to the weakening of certain groups of parasites. Sometimes a triplex may directly become a simplex from the linking together of two other groups of parasites at the same time.

Rarer Forms of Quartan Fever.

Quartan parasites are believed not to cause continuous fever, but very rarely they may cause subcontinuous or remittent fever. Such a condition is due to the presence in the blood of parasites of all ages, which, therefore, are continually sporulating and disturbing the metabolism, thereby producing the remittent type of fever.

Mixed infections may occur with either of the other two parasites, and an intermittent irregular fever be produced, only to be diagnosed by the microscope.

THE TERTIAN FEVERS.

Tertian malaria includes all the fevers caused by *Plasmodium vivax*. These fevers may be classified into:

1. Simple tertian fever—tertiana simplex.
2. Double tertian fever—tertiana duplex.
3. Irregular subcontinuous tertian fevers.

Tertian is the most widely distributed of all the malarial fevers, and the most common, for reasons already given (p. 637).

Simple Tertian Fever.

Simple tertian fever is characterized by attacks recurring every forty-eight hours, and separated by an apyrexial interval, which is the length of time required by *Plasmodium vivax* to pass from the merozoite to the fully developed schizont.

The clinical description may be divided into—(1) the attack of fever; (2) the apyrexial interval.

The Attack of Fever.—There may be no prodromata, or, on the other hand, these may be most characteristic. When present, they take the form of pain in the head and the back, and especially in the bones of the limbs—more particularly the joints—which lead to their being considered to be rheumatic, together with a feeling of lassitude and illness. On the day succeeding these sensations the patient may feel quite well, but on the next day they may recur. If treated in this stage, the fever may never develop, but if neglected, it will appear in the course of a few days.

After a feeling of illness, giddiness, nausea, or vomiting, with perhaps a slight rise of temperature, the patient suddenly becomes very cold and shivers, and his symptoms resemble in detail those already described for quartan malarial fever, except that they may not be so severe. In about ten to thirty minutes the warm stage begins.

As the chills diminish, sensations of warmth appear; at first pleasurable, they soon become intense, and the patient feels burning hot. The skin is hot, flushed, and dry; the conjunctivæ injected; the pulse full, quick, and often dicrotic, and the pains in the head, back, and limbs increase. A slight cough may be noted; vomiting is common, and sometimes diarrhœa occurs. Very often the white skin shows a sallow or slightly yellowish tinge, which is also present in native races, but can only be seen in the conjunctivæ. The heart-sounds are usually normal, but sometimes a soft systolic murmur can be heard. In the lungs, at times, sonorous and sibilant râles occur. The spleen is enlarged and tender, which is characteristic, and a soft murmur over the splenic area, like a uterine souffle, is said to be sometimes heard. Skin eruptions have been described; the commonest in our experience is erythematous or urticarial. Herpes may occur on the lips.

The temperature begins to rise before the chill, and continues to ascend during the cold stage, reaching a maximum in the hot stage, which may be anything from 102° F. to 108° F., but is generally about 104° F. or 105° F. The warm stage may last four or five hours, when it passes into the sweating stage.

The mouth becomes moist, and sweat gradually comes out all over the body, and soon a most profuse perspiration may take place, and the pulse, respirations, and temperature may fall to normal in about four hours, and the patient, as in quartan fever, goes off into a sleep. The attack lasts about ten to twelve hours, and generally begins in the morning, but may take place at any time of the day.

Peculiarities.—As in quartan, so in tertian fever, children may have neither chill nor sweating stage, and may, on the other hand, show convulsions.

Apyrexial Interval.—This lasts about thirty-six hours, during which the temperature is often subnormal. In the interval the patient may feel well, but his blood will show developing parasites, reduced erythrocytes, and a leucopenia with a mononuclear increase.

Double Tertian Fever.

When parasites mature on two separate days, fever is produced every day, which is therefore quotidian in type, and is called a double tertian (tertiana duplex). The attacks are similar to those described above, but usually are shorter, and, of course, the apyrexial interval is shorter. As a rule, the attacks begin at the same hour each day, but sometimes one attack is later than the other. Very often one attack is not so severe as the other, but if left to itself without treatment, it may become similar to the more severe attack. Double tertians may arise by a simple tertian anticipating. If this is continued after the double tertian is developed, or if one of the attacks of a double tertian anticipates, in course of time it will join in with the originally previous attack, so that a person who is in the sweating stage of one attack may suddenly start the cold stage of the other.

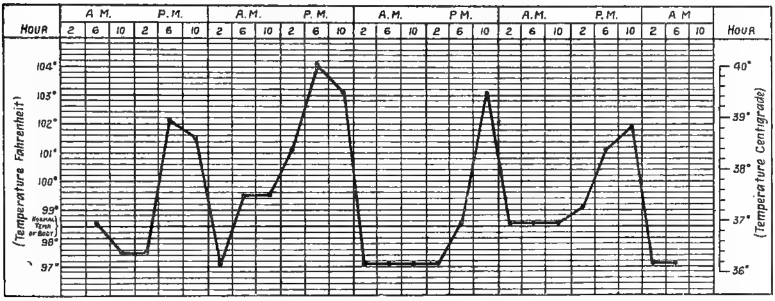

FIG. 294.—CHART OF A CASE OF DOUBLE TERTIAN MALARIAL FEVER IN THE GENERAL HOSPITAL, COLOMBO.

Clinical Course.—Left to itself, tertian malaria tends to a spontaneous cure after a series of attacks, but relapses may occur. Groups of more severe attacks alternate irregularly with groups of milder attacks. Usually, recurring attacks take place about the same time on the succeeding days.

The anæmia of tertian fevers is more easily overcome than that of quartan, and great exhaustion is only seen in old debilitated subjects.

Two interesting points may be noticed—(1) anticipation of the attacks; (2) retardation of the attacks. Anticipation of the attacks means shortening of the apyrexial interval, so that the attacks begin at short intervals. Retardation means prolongation of the apyrexial interval, and is generally due to the action of quinine, but may be due to spontaneous weakening of the parasite.

Irregular Subcontinuous Tertian Fevers.

Irregularity may be brought about by parasites maturing at different times on the same day, and thus producing an almost continuous fever, with exacerbations and remissions; but tertian fever is rarely duplicated—that is to say, it rarely shows two distinct attacks in one day. Prolongation of the attack produces a fever resembling the subtertian, while in very chronic tertians just the reverse may take place—viz., prolongation of the apyretic intervals—so that fever appears at the end of seven, eight, fourteen, or sixteen days.

Irregularity may also be produced by mixed infections of *Plasmodium vivax* with *Plasmodium malariæ*, or with *Laverania malariæ.*

THE SUBTERTIAN FEVERS.

Subtertian malarial fever derives its name from the fact that though really a tertian fever, its attacks are very prolonged. It is caused by *Laverania malariæ*, and though known as long ago as the days of Celsus, has in modern times been accurately studied by Baccelli, Marchiafava, and Bignami.

The various fevers classified together under the term 'subtertian' may be divided into:

1. Simple subtertian fever.
2. Double subtertian fever.
3. Irregular subtertian fevers.
4. Remittent subtertian fevers.
5. Bilious remittent fever.
6. Pernicious subtertian fevers.

1. Simple Subtertian Fever.

This form of subtertian fever usually shows intermissions based upon a tertian type.

The incubation period has been studied by Marchiafava and Bignami, who considered it to be of nine to ten days' duration when acquired by natural mosquito infection, and to vary from nine to nineteen days when acquired by experimental mosquito infection. Prodromal symptoms resembling those of tertian fevers may exist before an attack.

The cold stage may be entirely absent, but it often occurs, and is sometimes severe. Sometimes the attack begins with the warm stage, in which the symptoms are very severe pains in the limbs, back, and head, with gastro-intestinal disturbance in the form of vomiting, diarrhœa, and coated tongue. The skin is often flushed and dry and sometimes icteric, while the eyes are injected. The sweating stage is never absent, and may be marked. The spleen is usually tender, as well as the liver. The four-hourly temperature chart is most characteristic, for the invasion takes place with a rapid rise to 104° F. to 105° F., after which the temperature remains high, oscillating about 1° F. The oscillation which immediately precedes the crisis is larger than the others, and is called the pseudo-crisis. After this the temperature rises to its highest point (precritical elevation), and then suddenly falls (crisis) below normal, where it remains, as a rule, until the next attack. It may, however, rise from subnormal to normal, and just prior to the next attack show a distinct depression. This typical temperature may, however, be greatly masked by an absence of the sudden rise at the invasion, or of the precritical elevation, or by an exaggeration of the pseudo-crisis, making the angle attack appear double.

Lastly, the whole attack may be shorter than usual, and resemble, as regards the temperature, a simple tertian fever.

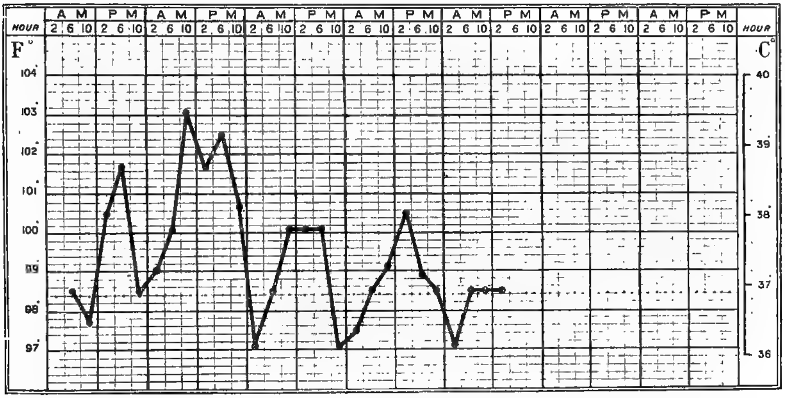

FIG. 295.—CHART OF A CASE OF SUBTERTIAN MALARIAL FEVER.

The curve is most typical on the second day, before quinine was administered.

The duration of the attack in subtertian fever is about twenty-four hours or more, while the interval will be twenty-four, ten, or even eight hours in duration, varying, of course, with the length of the attack.

2. Double Subtertian Fever.

This is a quotidian fever, caused by two broods of *Laverania malariæ*. The cold stage is less marked than in a quotidian fever, due to quartan or tertian parasites. The temperature rises rapidly, the fastigium is very short, and the fall is to below normal. There is nothing particular to remark about the warm or sweating stages, which resemble those of the simple subtertian fever. The whole attack only lasts six, eight, or twelve hours.

3. Irregular Subtertian Fevers.

When several broods of *Laverania malariæ* exist together in the blood, it is obvious that, instead of sporulation taking place regularly every day or every other day, it will be irregular, and hence the attacks will run into one another and produce an irregular type of fever, which is commonly met with on the West Coast of Africa.

4. Remittent Subtertian Fevers.

Remittent fevers arise by prolongation of ordinary attacks, or by anticipation or subintrance, so that two attacks become continuous, the onset of the second attack beginning before the first one is concluded. Duplication may also lead to a remittent fever.

These fevers may be mild or grave, and may become pernicious. The symptomatology is briefly as follows: After one or two days of prodromal lassitude, pains, and sensations of chilliness, etc., fever comes on without any cold stage. The skin becomes hot and dry, and often turns yellowish, and headache, with pains in the different parts of the body, are a source of trouble to the patient.

The tongue is coated; thirst is sometimes intense, and may be associated with vomiting and purging, together with pains in the region of the liver, spleen, and stomach. The toxins affect the brain, causing sleeplessness, restlessness, and delirium. The liver and spleen are both enlarged and tender, and at times there is slight cardiac dilatation on the right side. The temperature is characterized by high fever with remissions.

The time of the remission is by no means certain. It may take place in the morning and the rise in the evening. Under treatment the parasites rapidly disappear from the peripheral circulation, but last longer in the viscera, so keeping up the fever. Mild attacks get well under the week, but without treatment they would soon become the more serious or grave type of fever, which shows three variations —the first resembling typhoid in its clinical features; the second distinguished by the bilious vomiting and diarrhœa, with marked enlargement of the liver and jaundice, which is often called bilious remittent fever; and the third with a tendency to hæmorrhages, local gangrene, hæmoglobinuria and great weakness, called 'adynamic remittent fever.' Only the bilious remittent requires further consideration.

5. Bilious Remittent Fever.

This is a type of subtertian remittent fever in which there is great blood-destruction, and consequently much bile-production. We have seen it repeatedly in Africa, and it is said to occur in all highly malarious districts.

The attack begins as an ordinary remittent fever, but is associated with jaundice, bilious vomiting, and usually bilious diarrhœa, though in its place there may be constipation. The patient also complains of pain and tenderness in the stomach and liver. After a few days' illness the symptoms may gradually subside, or, with or without hiccough, epistaxis or hæmatemesis, the temperature may rise considerably, and the patient, becoming comatose, dies.

We have noted at times a curious intermission in the symptoms, unfortunately of short duration, after which high fever ensues, quickly followed by coma and death.

6. Pernicious Subtertian Fevers.

As already explained, the subtertian parasite may undergo its life-history in the capillaries of some one organ in particular. When this happens, the organ in question suffers, not merely from acute poisoning with the malarial toxins, but also from lack of nutrition owing to the blocking of the capillaries by swollen endothelial cells and by blood-corpuscles filled with parasites, leucocytes filled with pigment, free pigment and merozoites. These two conditions produce symptoms indicating the organ affected, and, moreover, produce a high mortality, hence the term 'pernicious fevers.' In addition to this localized type, a large number of parasites in the general circulation may also cause pernicious symptoms.

The pernicious fevers are classified into :

A. PERNICIOUS FEVERS WITHOUT LOCAL SYMPTOMS.

1. Algide pernicious fever.
2. Diaphoretic pernicious fever.
3. Hæmorrhagic pernicious fever.
4. Scarlatiniform pernicious fever.

B. PERNICIOUS FEVERS WITH LOCAL SYMPTOMS.

1. With cerebro-spinal symptoms.
2. With gastro-intestinal symptoms.
3. With cardiac symptoms.
4. With pulmonary symptoms.

A. PERNICIOUS FEVERS WITHOUT LOCAL SYMPTOMS.

Algide Pernicious Fever.—The patient is, as a rule, first seen in a condition of such extreme collapse as to make the practitioner suspicious of cholera. The nose is sharp, the cheeks sunken, the lips and extremities cyanotic, the nails livid, the pulse small, soft, and frequent, becoming thready and imperceptible, the skin cold and clammy, and the respiration laboured. The patient may, however, be conscious, and be able to answer questions and to complain in a weak voice of severe thirst. This is a very serious and fatal form of pernicious malaria, and generally kills the victim in a few hours.

Diaphoretic Pernicious Fever.—In this type the sweating of the third stage of an attack is so exceedingly copious that not merely is the bed saturated, but a pool may even form on the floor. Such excessive excretion of sweat is dangerous, as the patient becomes more and more exhausted as it goes on, and a most dangerous collapse may ensue.

Hæmorrhagic Pernicious Fever.—This form of pernicious fever is apparently rare. It is characterized by hæmorrhages from the skin and mucosæ of the nose, bronchi, intestines, stomach, and generative organs during the attack, but not during the intermission.

This condition rapidly produces acute grave anæmia, with thready pulse, coma, delirium, convulsions, and death.

Scarlatiniform Pernicious Fever.—Scarlatiniform pernicious fever is characterized by a diffuse scarlatiniform rash all over the body, with desquamation of the horny layer and erythema of the fauces, and may lead to a typhoidal state in which the patient dies.

B. Pernicious Fevers with Local Symptoms.

With Cerebro-spinal Symptoms.—Briefly, it may be stated that no diagnosis of hemiplegia or of any brain or spinal disease without such obvious cause as traumatism should be diagnosed in malarious districts without first examining the blood to see whether the subtertian parasite is present.

It would appear that almost any group of peculiar nervous symptoms, including even chorea, in a patient infected with malaria, may be the direct result of the parasites, and may therefore be amenable to treatment by quinine.

With this understanding, it is possible to mention a few of the many forms in which this protean malady may present itself, which may be classified as :

1. Comatose pernicious fever.
2. Delirious pernicious fever.
3. Tetanic pernicious fever.
4. Eclamptic pernicious fever.
5. Meningitic pernicious fever.
6. Hemiplegic pernicious fever.
7. Aphasic pernicious fever.
8. Amaurotic pernicious fever.
9. Bulbar pernicious fever.
10. Cerebellar pernicious fever.
11. Ataxic pernicious fever.

Comatose Pernicious Fever.—This may begin suddenly or slowly. If the latter, there may be weakness, sleepiness, headache, disturbance of vision, stupor, or delirium, which ends in coma. But more often the patient is brought to the hospital quite comatose. He lies flat upon his back, with usually no paralysis and no alteration in the reflexes. The pupils may be contracted and give the idea of opium-poisoning, while the patient cannot be roused to answer questions, but will only frown or groan.

Hæmorrhages may be found on the skin and in the retina. The urine, which may have casts and a little albumin, is usually passed involuntarily, as are the motions. The heart is dilated, and the pulse, at first slow, soon becomes quick, and towards the fatal termination very quick and thready. Respiration may be quiet or noisy. If death is to take place, the patient becomes colder and colder, the tongue dry and thick, and respiration ceases.

If he is about to recover, the coma will gradually pass away ; he will be able to answer questions when roused, and after a time gradually recovers consciousness. The speech is most peculiar, being scanning in character.

The coma may be present one day, but the next day the patient may be slightly better, with a subnormal temperature and a slower, fuller pulse ; towards evening, however, the temperature rises, and the coma returns. This second attack is, as a rule, fatal. The fever may be remittent or intermittent. In the latter case it returns before death. Quinine treatment by injection and otherwise appears to be of no avail at times, and after two or three days of coma, even when the parasites have disappeared from the peripheral blood, the person may die.

Delirious Pernicious Fever.—In this form, delirium is the most marked feature, and in a short time is followed by exhaustion, coma, and death. Such cases are apt to come on suddenly, and to be mistaken for drunkenness or sunstroke. The fever is usually very high. Recovery is supposed to occur, but we have never seen these cases end otherwise than fatally.

Tetanic Pernicious Fever.—Patients delirious from malaria may show trismus, contraction of the limbs, opisthotonus retraction of the abdomen, and conjugate deviation of the eyes. The contractions of the muscle may relax and increase as in tetanus, and there may be priapism. The attack may resolve, or end in death with high temperature.

Eclamptic Pernicious Fever.—Children during an attack of fever may develop convulsions, followed by stupor, or even coma and death.

Meningitic Pernicious Fever.—Fever with signs of meningitis may be found in young persons and children. The symptoms are vomiting, slow pulse, headache, retraction of the head, and rigidity of the neck, convulsions, hyperæsthesia, and irregularity of pulse, going on to coma and death.

Hemiplegic Pernicious Fever.—The patient may be suddenly taken ill with fever, and develop a typical hemiplegic attack.

Aphasic Pernicious Fever.—In this type motor aphasia develops with or without other paralyses.

Amaurotic Pernicious Fever.—During an attack of pernicious fever a patient may complain that he is unable to see. When treated with quinine, as a rule sight soon returns, but more rarely blindness may result, due to thrombosis of the retinal vessels, and consequently retinal hæmorrhages and optic neuritis. One eye only may be attacked. This condition must be differentiated from quinine amaurosis. In malarial amaurosis the pupils react to light, and vision is, as a rule, not completely lost. In quinine amaurosis the pupils are widely dilated, and do not react to light, while other symptoms of cinchonism, such as deafness, severe tinnitus aurium, etc., will be present.

Bulbar Pernicious Fever.—A fever with bulbar symptoms—that is to say, difficulty of speech and deglutition, with facial paralysis, or with the weakening of the muscles, as shown by disturbances of equilibrium in a malarial district—may be a pernicious fever, and can only be diagnosed by a blood examination.

Cerebellar Pernicious Fever. — The patient presents cerebellar ataxia and vomiting, and complains of severe headache.

Ataxic Pernicious Fever.—This probably belongs to the same class as the bulbar, for the symptoms—slow and scanning speech, great muscular weakness, exaggeration of tendon reflexes, ataxia, together with vomiting—all indicate a bulbar lesion. Subtertian parasites are found in the blood. At first there is no fever, but this may develop later. Such patients generally recover on quinine treatment, or, indeed, they do so spontaneously.

Pernicious Fevers with Gastro-intestinal Symptoms.—The gastro-intestinal symptoms may be classified into:

1. Choleraic pernicious fever.
2. Dysenteric pernicious fever.
3. Hæmorrhagic pancreatitis.

Choleraic Pernicious Fever.—This is merely a great exacerbation of the ordinary gastro-intestinal symptoms commonly met with in malarial fever. There is vomiting, abdominal pain, and severe diarrhœa. A microscopical examination of the dejecta may show a few leucocytes in stages of degeneration. An examination of the blood will show the parasites.

During the attack the patient is pale or cyanotic, the eyes sunken, the skin cold and clammy, but the temperature may be raised, and hiccough, severe thirst, and painful cramps in the lower limbs may also be present. The urine is scanty or suppressed. Collapse, delirium, or coma, may precede death, or the patient may be sensible to the end. If the patient is to recover, the algidity diminishes, the diarrhœa ceases, and after a long sleep he awakens refreshed, and convalescence sets in.

Dysenteric Pernicious Fever.—In this type there are motions which contain blood and mucus tinged with bile. The fever is high, and there is great distress and prostration, with small rapid pulse. Under quinine treatment the patient may rapidly recover.

Hæmorrhagic Pancreatitis.—Hæmorrhagic pancreatitis, which is by no means unknown in Ceylon, has been found post-mortem to be caused by malarial parasites, but, as far as we know, no diagnosis of the condition has been made during life. The symptoms are those usually described for hæmorrhagic pancreatitis from other causes.

Pernicious Fevers with Cardiac Symptoms.—The right heart has been noticed to be enlarged in attacks of malarial fever, and sometimes these symptoms become marked, with severe pain in the cardiac region, accompanied with vomiting of blood, while the patient passes into an algide condition and dies.

Pernicious Fevers with Pulmonary Symptoms.—These may be: (1) Pneumonic; (2) pleuritic.

Pneumonic.—This is generally of the nature of a broncho-pneumonia, and is accompanied with blood expectoration in the red corpuscles of which parasites may be seen, dyspnœa, and cough. The symptoms are better in the remission of the fever, and worse during the attack. The blood is full of parasites. In many cases broncho-pneumonia in malarial patients is not due directly to the malarial parasites, but is a complication due to the pneumococcus.

Pleuritic.—Intermittent pleuritic pernicious fever has been described, with sharp pricking pain, dry cough, and friction sounds, which improve in the remission, and become worse again in the attack.

Appendicular and Peritoneal Symptoms.—Appendicular and peritoneal malarial attacks have been described by some authors.

Orchitic Symptoms.—Cases of acute orchitis due to malarial parasites have been described by various observers.

Dry Gangrene.—Dry gangrene of the feet and legs has been described by Tomaselli and others as being due to endarteritis of malarial origin.

CHRONIC MALARIA.

Chronic malaria may result from infection by any of the three malarial parasites, but is usually caused by *Laverania malariæ*, the subtertian parasite.

The symptoms of chronic malaria are repeated attacks of slight fever, which may pass unnoticed; enlargement of spleen and liver; and pigmentation of the skin and mucosæ. This pigmentation is particularly to be noted in the tongue in dark races, while in white races Gerhardt's urobilin icterus may be seen in the skin. Other symptoms are œdema about the feet, associated with anæmia, which may be marked; the presence of malarial parasites in the peripheral blood during an attack of fever; and often palpitation and dizziness, bronchitis and digestive troubles, and a general disinclination for exertion and work. The urine shows an increase of urea and urobilin. If this state of affairs is allowed to continue, it may pass into malarial cachexia, with enormous enlargement of the spleen, which is firm to the touch and not tender or painful, associated with a profound secondary anæmia, and great reduction of red cells and hæmoglobin, with increase of mononuclear leucocytes.

In malarial cachexia the apyrexial intervals are long, during which search may in vain be made for the parasite in the peripheral blood, but it is usually found during the febrile attacks, which may be quite mild. This is a condition, however, in which blood examination does not help the diagnosis as it does in other forms of malaria, and the clinical symptoms require to be studied, for the disease resembles kala-azar, while it may also be mistaken for agchylostomiasis.

Chronic malaria, of course, is due to insufficient treatment of the acute disease by quinine.

Malarial Relapses.—The cure of an attack of malaria, unfortunately, does not end the disease, for relapses are the rule and not the exception ; in fact, using an expression of Mannaberg's, ' Malaria is one of those infectious diseases in which a relapse may be considered as an essential feature.' The reason is that the parasites are not all killed off by the quinine. There are two different types of relapses : the first, after a short interval, may be called the true relapse ; the second, after a longer interval, may be called the recurrence. Relapses and recurrences are probably caused by parasites belonging to the cycle of schizogony, and by the parthenogenesis of the macrogametocyte, which belongs to the cycle of sporogony.

Relapses of quartan fevers take place at irregular intervals, and the suggestion that they are most usual at about the twentieth day is not correct. Tertian fevers relapse most commonly from the fifth to the eighteenth day, and subtertian about the end of a week after the original attack, but these times are extremely variable. These relapses are historically interesting, as they probably represent the quintans, sextans, septans, octans, nonans, etc., of ancient authors.

Recurrences take place after long intervals without fever and without reinfection. Exactly how long the parasites can lie dormant in the human body and then wake to activity and cause fever is not known. Intervals of two and three years are readily credited nowadays, but it is in our experience certain that the length of time may be much longer.

Parasites can certainly be found in the blood of persons long after they have left the tropics ; thus, Ross mentions that they were found in a case in Liverpool four years after absence from any malarious locality, and also states that his own father suffered from attacks once or twice a year, even after nine years' residence in England.

It is probable, then, that the old idea that the malarial parasite can exist or lie dormant for years in the system, and awake to renewed activity when given a suitable opportunity, is true. During the apyrexial intervals it must, of course, be going through the cycle of schizogony, but not in sufficient numbers to cause disease. These parasites will increase rapidly and cause fever when the general vitality of the body is lowered by any of the predisposing causes, already mentioned, coming into action.

Malarial Reinfections.—In tropical countries where there are plenty of Anophelines and plenty of people, European and native, adults and children, with numerous gametocytes in their blood, reinfections are found to be common. Many cases of apparent recurrence in these countries must be reinfectious, which, of course, may be with the same or a different species of parasite from that causing the first fever. Repeated infections are the great cause of the quotidian and irregular fevers of the tropics.

Latent Malaria.—This term is employed to denote cases in which without any sign of illness, malarial parasites can be found in the blood in small numbers. Craig states that out of 1,267 cases in which malarial parasites were demonstrated in the blood, 21 per cent. were latent, and the majority of these were found to be caused by the subtertian parasite.

Masked Malaria.—Malaria is capable of being masked or concealed by some concurrent disease—*e.g.*, dysentery or phthisis. Another form of masked malaria is when the symptoms indicate some other illness, while a blood examination shows that the real cause of the disease is malaria. Thus, after an accident, the symptoms may point to cerebral abscess, but, on examination of the blood and the discovery of the parasites, followed by treatment with quinine, the urgent symptoms disappear. Masked malaria is generally caused by the subtertian parasite. The more important forms of masked malaria are neuralgias, particularly of the trigeminal, and especially of its frontal branch, paralyses and chronic diarrhœa, and also, according to Craig, pneumonia. These conditions emphasize the importance of systematic blood examination in all cases of disease of the tropics. Under the heading '*Masked Malaria*' must come cases of 'Malarial Pseudo-Addison's Disease,' in which patients who have been suffering for years from malarial infections, with or without severe attacks of fever, develop diffuse or patchy pigmentations, with severe asthenia, wasting, and diarrhœa, with or without blood in the motions. The spleen is not enlarged, and parasites are seldom found in the peripheral blood, though at times leucocytes containing hæmozoin may occur.

These conditions are due to the localization of the parasites in the supra-renal capsules.

Congenital Malaria.—The question of congenital malaria has been much debated, but Dumolard and Viallet have recorded a case in which a woman suffering from malaria gave birth to a child, in which blood from the umbilical cord during life and from the heart after death contained malarial parasites identical with those in the maternal blood and placenta.

Complications.—Many other diseases may occur in the human body at the same time as an attack of malaria, but of all, the most important are typhoid, dysentery, pneumonia, and nephritis.

Typhoid, as a complication, is, of course, due to the *Bacillus typhosus* occurring in a person who is also infected by a malarial parasite, and in that sense, therefore, the old term 'typho-malaria' is correct.

Dysentery may be a complication due to the *Entamœba histolytica* or to the dysenteric bacilli, but it may also be directly caused by the malarial parasite alone.

As to whether there is or is not a malarial pneumonia is a vexed question ; personally, we are of the opinion that a severe subtertian fever may produce symptoms resembling a pneumonia, but that true lobar pneumonia, when present in a malarial subject, is due to the pneumococcus, and is therefore a complication.

Nephritis may be found in tertian and subtertian fevers, being directly due to the irritation of the kidney by the malarial toxins.

Sequelæ.—The possible sequelæ of malaria are very numerous, and may be classified into those belonging to the nervous system and sense organs, the blood, the liver, and the spleen.

The subtertian parasite may leave severe traces of its action upon the brain after pernicious attacks, and, indeed, the mind may never regain its old condition. Apart from the milder alterations of disposition and character, actual insanity in the form of mania or melancholia may result.

Neuritis in some form is sometimes of malarial origin, but it is quite possible that alcoholic and arsenical poisoning, and, indeed, beri-beri, may have been confused with it. Neuralgias have already been mentioned, and are probably in some cases due to the direct influence of the malarial toxins. Tinnitus aurium, vertigo, deafness, anosmia, and loss of taste, are said in some cases to be malarial in origin.

Severe and long-continued anæmia may result as a consequence of malaria caused by the subtertian, and much more rarely by the other parasites. The classification and characters of these anæmias have already been given in the section on Pathology, to which reference should be made (p. 649).

Cirrhosis of the liver of malarial origin is, in our experience, much less frequent than admitted by many writers. Cirrhosis of the liver is common in the tropics, and in certain cases is due to alcohol ; but one of the writers has pointed out that, at all events in Ceylon, a polyfibrosis of liver, pancreas, and kidney, can be met with which has no malarial origin.

The enlargement of the spleen has already been described, and rupture as the result of blows or injuries is by no means unknown, though not common, and requires prompt surgical attention. We have only come across one case in our experience.

Diagnosis.—A positive diagnosis may be made if—(1) the fever shows the typical quartan and tertian periodicity, but a quotidian periodicity has no diagnostic value, as it may be found in many other fevers ; (2) parasites are found in the peripheral blood ; (3) hæmozoin is recognized in the mononuclear leucocytes. Malaria cannot, however, be eliminated from the diagnosis when all three are absent. Splenic puncture, and the subsequent examination of the blood obtained in this way, would help considerably, but is not devoid of risk. A marked mononuclear increase may arouse suspicions, but by itself is quite useless.

It is generally stated that a fever which within four days is not influenced by quinine in full doses is not malaria. This is correct as regards malarial fevers due to tertian and quartan parasites, but not always as regards those caused by the subtertian parasite. We have met with cases in which the fever has remained unaffected while the parasite can be found in the peripheral blood, notwithstanding several weeks' quinine-therapy by various methods.

In malarial cachexia James has pointed out that the microscopical is inferior to the clinical examination, drawing attention to the fact that a four-hourly temperature-chart carefully kept during one of the febrile attacks will often show the typical curve of subtertian fever. In such difficult cases the clinical signs, together with the reaction of the disease to quinine, must be utilized.

In latent malaria the frequent increase of the urobilin in the urine may be of some slight help in the diagnosis, as pointed out by Plehn, together with indefinite periodical rheumatoid pains.

The differential diagnosis of the various forms of malarial fever should be confirmed, no matter how evident the clinical symptoms may be, by microscopical examination.

The most important diseases to differentiate from malaria are typhoid, insolation, liver abscess, kala-azar, malta fever, influenza, yellow fever, dengue, and seven-days fever. For the differential diagnosis see the chapters on these fevers.

The pernicious forms of malaria, in whatever way they attack the patient, will in most cases be readily diagnosed by blood examination, as will also the masked form of the disease.

Prognosis.—The principal factors upon which a prognosis can be made are climate, race, age, sex, species of the parasite, type of the fever, presence or absence of complications, duration of the symptoms, and idiosyncrasy against quinine.

With regard to climate, the prognosis will be worse for warm climates, and in low-lying places with high air-temperatures.

As regards race, the resident of the Temperate Zone not having acquired the disease in childhood, on becoming infected in the tropics has not so good a prognosis as a member of a native race. Elderly and feeble persons or young children have also a worse outlook, and pregnancy may complicate the disease, with abortion.

Tertian and quartan parasites afford a better prognosis than subtertian, in which case the patient is decidedly in greater danger.

Simple quartans and tertians give the best prognosis ; quotidian fevers are more serious, subtertian fevers still worse, and pernicious symptoms most grave.

Complications increase the gravity of the case, especially typhoid and gastro-intestinal disturbances.

The prognosis is bad if the symptoms have gone on for some time without treatment or without apparent improvement, notwithstanding quinine-therapy.

If a person is definitely unable to stand the usual doses of quinine, he should not be allowed to live in the tropics, as the prognosis in a case of subtertian malaria must be very serious.

The mortality among natives is usually low, but among Europeans on the West Coast of Africa it is high.

With regard to statistics, there are great errors in the diagnosis, kala-azar, agchylostomiasis, and typhoid being frequently grouped together under the heading ' Malaria.'

There can, however, be no doubt that malaria causes the greatest amount of sickness in all tropical countries, and may in certain localities be largely responsible for the death-rate, while in others it may not contribute nearly so largely.

Treatment.—The aim of the treatment of malaria is to kill the parasites, and so prevent further mischief, and to aid the excretion of the toxins and relieve the symptoms of the patient.

Fortunately, since the days of the Countess del Chinchon, the world has known the value of cinchona bark in malaria, and later it learnt that this important action was due to an alkaloid, quinine, which exists in the bark in the form of a hydrate. In 1867 Binz showed that quinine killed infusoria, and he believed that this action was due to its checking oxidation.

Quinine is usually sold in the form of the sulphate, $[(C_{20}H_{24}N_2O_2)_2.H_2SO_4]_2.15H_2O$, which is only soluble 1 in 800 of cold water, but is readily soluble in water acidulated with a mineral acid. The solution gives a bluish fluorescence.

It must be remembered, however, that it may not be pure, and may contain lime, chalk, magnesia, starch, etc. It is also important to remember that it is incompatible with alkali, alkaline carbonates, and astringent infusions.

Quinine sulphate is by no means the best preparation, for the hydrochloride, $(C_{20}H_{24}N_2O_2).HCl.2H_2O$, is soluble 1 in 40 of water ; but better than this are the acid salts of the sulphate, called the ' bisulphate,' $(C_{20}H_{24}N_2O_2)H_2SO_4.7H_2O$, which is soluble 1 in 11 parts of water, and of the hydrochloride, called the ' bihydrochloride, ' $(C_{20}H_{24}N_2O_2)2HCl$, which is soluble 1 in 1 of water. Numerous other preparations are on the market, of which quinine bihydrobromide is recommended in persons who suffer from deafness, and quinine valerianate in those who are very nervous ; while quinine tannate, which is not nearly so bitter as the other compounds, especially when made up with chocolate, has been used by Celli in quinine prophylaxis for children and in cases of hæmoglobinuria.

Euquinine, which is quinine ethylcarbonate, $C_2H_5O - CO - OC_{20}H_{23}N_2O$, is also not so bitter as the ordinary preparations, and is therefore suitable for administration to ladies and children, but it has the disadvantage of being expensive and very insoluble in water, and must be given in cachets or dissolved in acidulated water. It has not such deleterious effects on the stomach and nervous system.

Another remedy which contains quinine sulphate, and which was much vaunted in days gone by, is Warburg's tincture, which is said to be prepared by macerating for seven days the following ingredients—

	Grains.
Aloes socotrinæ	240
Rhei	80
Fructi archangelicæ officinalis	80
Radicis inulæ helenii	40
Croci	40
Fructi fœnicali	40
Cretæ preparatæ	40
Radicis gentianæ	20
Radicis curcumæ zedoariæ	20
Cubebæ	20
Myrrhæ	20
Polypori officinalis	20
Opii	2½
Piperis nigræ	4
Cinnamonis	8
Zingiberis	8

in a pint of 60 per cent. alcohol for a week; then pressing, filtering, and dissolving in the filtrate—

	Grains.
Quininæ sulphatis	175
Camphoris	20

and after three days' filtering, making up to the pint with alcohol. The dose of this mixture is 1 to 4 drachms.

Other preparations can hardly be said to have any particular interest.

In order, however, to bring these various preparations into line with one another, it is necessary to have some arbitrary standard, and this is generally taken as quinine sulphate, which is reckoned as equal to 1. The hydrochloride will then be 0·9, the bisulphate 1·24, the bihydrochloride 1·02, the bihydrobromide 1·23, the valerianate 1·01, the tannate 3·67, euquinine 1·0, and Warburg's tincture 1·09.

Effects on Man.—When taken by the mouth, quinine should be dissolved in the acid gastric juice, converted into the bihydrochloride, and absorbed completely into the blood from the stomach, especially if food is taken at the same time. If this does not happen, then such a salt as the sulphate may not be absorbed at all, as it will be precipitated in the alkaline intestinal contents. When given in large or frequent doses, it is apt to irritate the stomach. As to what happens to it in the blood, there are two distinct views—one pointing to rapid elimination, and the other to the fact that it undergoes changes in the tissues. It would appear to be retained longer in the body if absorbed together with food.

It can also be administered by intramuscular injections, when it is said to be largely precipitated at the site of the injection. We have no knowledge personally of this precipitation, and our experience is that intramuscular injections have been most satisfactory, though it must be admitted that there are observers who think that administration *per os* is more valuable than that by intramuscular injections. It may also be given intravenously, as will be explained later.

Quinine in small doses is a vascular tonic, but in large doses it is a cardiac depressant, producing a fall in the arterial pressure, with decrease in the pulse-rate and strength. This is an important matter, to be remembered in administering the drug to the old and the feeble, especially by intravenous or intramuscular injections. On the nervous system it acts as a stimulant, and also increases the flow of blood to the brain. In the tissues it is partly destroyed by oxidation, and therefore the whole quantity administered is hardly likely to be obtained in the urine. Excretion takes place by the kidney almost entirely in the form of quinine dihydroxyl. It can be recovered from urine by acidulating with sulphuric acid, treating with solid picric acid, filtering until clear, digesting with 3 per cent. caustic soda solution, and extracting with chloroform, from which the quinine can be obtained by evaporation.

When given in large doses, the cerebral congestion which it produces causes buzzing in the ears, deafness, due to congestion of the middle ear, and headache, both of which can be treated by bromides, with or without a little ergot. It may also cause erythematous, erythemato-papular, vesicular, and urticarial eruptions.

In persons who have suffered from malaria there is no doubt that quinine can cause hæmoglobinuria, but the way in which it acts is doubtful. Stephens believes that the hæmoglobinuria stands in no relationship to the dose of quinine, and, further, that a second dose may not produce the result, and that it is the blood condition of the malarial patient which is the determining factor. Our experience has tended to show that there is a direct relationship between the quinine and the hæmoglobinuria. Quinine acts in this way by causing hæmolysis of the red corpuscles. Stephens and Christophers found that 0·001 to 0·00082 gramme of quinine hæmolyzed 1 c.c. of a suspension of normal human red cells at 37° C. The hæmolytic action naturally increases the quantity of bile produced. This deleterious action can be prevented by giving calcium chloride, which increases the resistance of the red cells to hæmolysis.

Amblyopia may result as the effect of large doses of quinine, and appears to be due to constriction of the retinal arteries in temporary cases, and to degeneration of the retinal ganglion cells and their processes in permanent cases.

Quinine appears to act upon the uterus, and may therefore produce an unpleasant effect in pregnancy, though whether this is really due to the quinine or to the malaria, or to the two combined, is doubtful.

Effect upon Malarial Parasites.—Quinine appears to particularly affect the merozoites, trophozoites, and schizonts, and to act much less vigorously, if at all, upon the gametocytes.

It appears to act most vigorously upon the merozoites, perhaps because they are free in the plasma; next upon the young trophozoites, whose cytoplasm is broken up, and finally it and the nucleus destroyed; but it has no such powerful effect upon the fully-grown schizont, and will not prevent sporulation.

With regard to the gametocytes, it probably has a deleterious action upon the young forms, but certainly not upon the fully-grown micro- and macrogametocytes. It is thought probable that it may act upon the very old form of microgametocyte, but this cannot take place, as a rule, with regard to the ordinary fully-grown microgametocyte, for Anophelines can be infected by the blood of persons containing the two kinds of gametocytes even when treated vigorously with quinine. On the macrogametocyte, particularly that of *Laverania malariæ*, it appears to have no action. Hence to get the full effect of quinine on the parasites it must be present in the blood at the time of sporulation, in order that it may kill the merozoites, young sporonts, and schizonts. In order to produce this effect, it is judged that the quinine must be present in the blood in a strength of at least 1 in 20,000.

Time of Administration.—From the above it will be obvious that the best time to give quinine to a healthy person for purposes of prophylaxis, or to a convalescent for purposes of effecting a cure, will be at meal-times, and preferably directly at the end of the meal, so that it can enter the blood with the products of digestion, and so obtain its fullest action. It has been our rule in most cases to advise that it should be taken directly after the early morning meal.

The hæmolytic action of quinine must be remembered, and the fact that it may by this action give the liver more work by extra bile production. Consequently, it is most necessary to remind the above class of patients to take care that the bowels are open regularly, and to correct by suitable aperients any irregularity that may exist.

With regard to mild quartan and tertian fevers, there is not the slightest doubt that excellent effects are obtained by giving the drug four hours before the attack—*i.e.*, before the sporulation of the parasite is due. In this way the merozoites are most likely to be killed. This may be modified by giving the drug twice daily, one dose of 10 grains by the mouth in the morning, and the other dose of 10 grains at the above-stated time. This method we have found most useful, as it allows for irregularity in sporulation.

In many cases, however, we give the drug three times a day, without regard to the conditions of parasitic life, and this method is apparently not less successful.

In more severe forms of quartan and tertian, and in cases of subtertian fever in which the patient is seen for the first time during the attack, the drug should be given hypodermically or by the mouth, when it may be administered on the fall of the temperature, when the gastric irritation is lessening, and then continued by one of the above methods.

In cases of serious and of pernicious attacks, time must not be wasted in waiting for temperatures to fall or for symptoms to improve, otherwise the patient will die, and there must be no hesitation in giving either an intramuscular or an intravenous injection, according to the severity of the symptoms.

Method of Administration.—For practical purposes there are only four methods of administration:

1. By the mouth.
2. By the rectum.
3. By intramuscular injections.
4. By intravenous injections.

By the Mouth.—If expense is no object, take the most soluble drug that can be got, and use either the bihydrochloride or the bisulphate; otherwise the sulphate must be used. In cases of ladies or children euquinine may be used with advantage, but it should be remembered that it is very insoluble and expensive.

The forms in which the chosen drug may be administered are:

1. Powder.
2. Solution.
3. Tabloid, tablet, or pill.
4. Cachet or capsule.

It is presumed that no doctor would allow his patient to take quinine in a cigarette-paper, though non-medical people are found who have got into the habit of using this method.

As regards the powder, it is an efficient method of administering the drug to the healthy, if given directly after a meal, but the taste is most unpleasant. It is certainly the cheapest method.

The acid preparations—for example, the bihydrochloride and bisulphate—may be dissolved in water, but should have some flavouring added to disguise the taste, while the sulphate requires an acid, which may be provided by suspending some of the powder in natural limejuice; but in order to dissolve the sulphate properly a mineral acid should be used, in the strength of 1 minim to each grain, but more than this will be required if the unpleasant after-taste is to be avoided.

In hospitals the sulphate must be used, as it is cheap and effective, but it is as well to have it periodically reported upon by an analyst, in order to see what is really being given to the patients. For hospital use it may be dissolved in dilute sulphuric acid, and have some cheap form of flavouring added.

We have used Warburg's tincture on the West Coast of Africa with apparent success in cases of chronic subtertian infection, which resist the ordinary methods of administering quinine, but care is required, as it has a depressing effect upon the heart in these cases.

Tabloids, tablets, and pills are pleasant methods of taking quinine for prophylaxis, convalescence, and mild attacks. Moreover, they are extremely useful for journeys, being readily carried, but in order to be successful they must not be old and hard. The hydrochloride or bisulphate should be used and the solubility tested from time to time in water, otherwise the tabloid must be reduced to powder and taken as indicated above.

Pills and capsules are quite good when fresh, but they are apt to get hard when old, and are then useless, and must be opened and the powder used, if they form the only supply available.

The quinine tannate chocolates are, of course, only used for prophylaxis in children.

By the Rectum.—This method may be useful in gastric disturbance, but is not to be compared with the intramuscular. Twenty grains of the bihydrochloride is made into a solution in water, and then mixed with an ounce of mucilage of starch solution, and used as an injection. It is advisable to add a few drops of tincture of opium.

Intramuscular Injections.—We are not in favour of hypodermic injections of quinine—*i.e.*, of injections simply under the skin—but strongly recommend intramuscular injections in all cases of malarial fever in which there is gastric disturbance, or in which, for any reason, the quinine is apparently failing to act, or in which the disease is becoming chronic, or in serious subtertian infections. For this purpose the bihydrochloride should be dissolved in normal (0·75 per cent.) saline solution, and carefully sterilized. Bacelli's formula is 10 grammes of quinine and 0·075 gramme (1⅙ grain) of salt dissolved in 10 grammes (2½ drachms) of water, one-tenth of which is used for an injection; but the greatest care must be taken that this solution is properly sterile. A good formula for a solution which does not cause pain is Gagli's or Giemsa's: Quinine hydrochloride, 10 grammes; aquæ destillatæ, 10 grammes; æthyl urethan, 5 grammes, of which one twenty-fifth portion is used for an injection.

If, however, the solution is to be prepared and sterilized while the patient is waiting for treatment, much time is lost. We therefore recommend the tropical practitioner to purchase and keep by him the sterilettes, which are little hermetically sealed vials, containing either a gramme (15 grains) or half a gramme (7½ grains) of quinine in solution. These sterilettes may be purchased from Squire and Sons, or Martindale, of London; Nachfl, of Berlin; or Molteni, of Florence. Giemsa's solution may be obtained in similar sterile vials from L. Bartels, Hamburg.

The technique is simple: First cleanse the skin of the patient carefully with 1 in 20 carbolic lotion; then break off the glass seal of the vial at the nick in the neck, and pass the open mouth of the vial through a flame; then draw up the contained fluid into a sterilized all-glass syringe provided with a platinum iridium needle. Plunge the hypodermic needle deeply into the deltoid or gluteus maximus, and make the injection. Withdraw the needle, and place a little pad of wool, wrung out in 1 in 40 carbolic lotion, on the site of the injection. Performed carefully in the above manner, there need be no fear of tetanus or abscess formation, and the injection can be repeated at will. If necessary, a stimulant or an injection of ether may be given in the old and feeble before this intramuscular injection. After repeated injections of quinine, even if administered antiseptically, hard swellings may appear at the seat of the injections. In such cases the hypodermics should be stopped for a few days, and an ice-bag may be applied to the painful part.

Intravenous Injection.—In cases of pernicious infection with subtertian parasites, no delay should be made in giving the patient an intravenous injection, but the effect of quinine on the circulation must be remembered, and if the pulse is bad, it is advisable to give a hypodermic injection of ether as a preliminary. The same vials and apparatus should be used in the intravenous as in the intramuscular injection.

The injection should be made into the median basilic or median cephalic veins, and not less than 1 gramme (15 grains) should be injected at a time. The skin over the selected vein should be rendered thoroughly aseptic by soap and water and carbolic lotion, and then a bandage tied round the arm, so as to retard the flow of venous blood and make the selected vein stand out. Then the needle should be inserted into the vein (care being taken that there is no air in needle or syringe) in a sloping direction, with the point towards the heart, so that the injection can flow with the circulation. The point of the needle should be felt to be loose (*i.e.*, in the vein). The bandage must now be loosened and the injection made *slowly*, the effect on the pulse being noted. The needle is now withdrawn, and an aseptic pad fixed in position by a bandage.

Dose.—To adults we generally give three times a day by the mouth 5 to 10 grains of the ordinary preparations (sulphate, hydrochloride, etc.). The routine treatment in the Ceylon clinic and hospitals is a mixture composed of quinine sulphate, 5 to 10 grains; dilute sulphuric acid, 5 to 10 minims; syrup of orange, 1 drachm; distilled water, 1 ounce. We give euquinine in slightly larger doses, though there is no danger in administering large doses.

By intramuscular or intravenous injections we give 10 to 15 grains, by the rectum 30 grains; but when given by the last method, some tincture of opium should be added, to prevent irritation, which otherwise is liable to occur. Five or ten grains of potassium bromide added to each dose of quinine will, to a certain extent, prevent tinnitus aurium. In cases in which the heart is weak a few minims of tincture of digitalis should be prescribed.

Children suffering from malaria stand quinine well, and the minute doses advised in so many treatises on the diseases of children are, in our experience, utterly inadequate in the tropics. Infants under one year of age may receive from ½ grain to 1½ grains six times a day; children between one and three years of age from 1 grain to 2 grains six times a day, and those between three and ten years 2 to 3 grains six times a day.

Nocht has advised the administration of quinine in small repeated doses of 2½ grains five times a day. This method is useful when there is a tendency to hæmoglobinuria and in pregnant women in whom the administration of full doses may induce abortion ; but this action has been greatly exaggerated, many cases ascribed to quinine being due to some other cause. We have often given 15 grains of quinine daily to pregnant women, but divided into small doses of 2 to 3 grains (Nocht's method), and in severe cases have pushed the drug without bad effects. The addition of a little opium may prevent bad effects.

Duration of Treatment.—When the fever has subsided and the patient is feeling better, the administration of quinine must not be discontinued, because there is the fear of a relapse, caused by parasites which have not yet been destroyed, and which may be living in the spleen ; or, again, there is the fear of the parthenogenesis of the macrogametocyte. In order that the treatment may be successful, the quinine must be continued for a long time. Our routine practice has been to continue with 10 grains in the morning and 10 grains in the evening for a week after the cessation of the fever, 5 grains in the morning and 5 grains in the evening for about two weeks after, then 5 grains every day, with a double dose once a week, for about three months. In some cases when the fever has ceased it is advisable to associate some iron and arsenic with the quinine, but these drugs should not be given during the febrile attack.

Prophylactic Use.—This will be discussed in the section on Prophylaxis (p. 683).

Other Drugs.—It is almost a work of supererogation to mention other drugs in the treatment of malaria, such as cuprein, methyl blue, atoxyl, and treatment by the serum of immune animals, and by violet light or in the dark. Methylene blue, however, has been used by several authors in the dose of 2 grains every four hours. In our experience its efficacy cannot be compared to quinine.

Symptomatic Treatment of Acute Malaria.—The practitioner who works in the tropics must be prepared often to do the nursing as well as the medical treatment. When the attack begins, the patient must go to bed, and in the cold stage wrap up well with blankets. At the same time arrangements must be made in case of sickness or diarrhœa. The treatment of this and the warm stage must be to encourage perspiration, by warm lime-drinks, hot tea, etc., in order that the toxins may be passed out as quickly as possible. Ziemann recommends hot-air baths to bring on the perspiration. We have tried this method a few times, but have not been greatly impressed with the advantages.

The headache may be relieved by cold applications, and where there is no ice, dissolve some salt and juice of fresh limes or lemons, together with some vinegar or weak acetic acid and Florida water or eau-de-Cologne in a small basin of water, and, after soaking handkerchiefs in this mixture, apply them one after the other, changing as they get warmed, to the patient's forehead.

A little stimulation of the auricular branch of the pneumogastric by applying some of this cool lotion to the lobule and behind the ear is most refreshing to the patient.

Another method of relieving the headache and pains about the body is to give phenacetin and caffein. Phenacetin or antipyrin should only be given in small doses, and not to debilitated patients.

When the sweating begins, the patient usually feels much better, but care must be taken to change the damp clothing, and when this stage is drawing to a close a sponge over with tepid water is most refreshing, and the person will probably go to sleep, and wake feeling much better.

Treatment of Symptoms and Special Conditions.—Vomiting is often distressing, and can be relieved by sips of iced soda-water or champagne. When there is no ice, cover the bottle with a thin layer of flannel soaked in water, and hang in the breeze. If these simple remedies fail, and the symptom is really urgent, apply a mustard-leaf to the pit of the stomach, or give a mixture containing chloroform or a hypodermic of morphine. If, despite all this treatment, the vomiting still continues, the stomach may be washed out with slightly alkaline water. Hiccough is not often present, and would be a most unpleasant sign. It can be checked by the mustard-leaf, by codein, or by a hypodermic of morphia (gr. $\frac{1}{4}$).

Not infrequently the patient is worried by a sharp, dry cough, which is best treated by codein or morphia in some form, *e.g.*

Codeinæ	gr. $\frac{1}{4}$.
Syrupi tolutanæ	ʒi.
Aquæ chloroformi	ad ℥i.

administered every four hours.

Constipation must not be allowed, and should be promptly relieved by a dose of calomel (1 to 3 grains), if necessary, followed by a saline. Ziemann strongly recommends washing out the rectum with warm normal saline solution as a routine practice, but though we have used this in bad cases, we have no experience of it as a routine practice.

Diarrhœa is at first useful in ridding the body of excess of bile and other waste products. Prolonged diarrhœa must be treated with astringents (bismuthi subnitratis or salol gr. x. every 4 hours). Meanwhile it should be borne in mind that though quinine is absorbed by the stomach, still, with much diarrhœa there is often gastric disturbance, and therefore, if the drug is given by the mouth in these conditions, its utility may be small.

Splenic pain and liver pain are not, as a rule, severe enough to make special treatment needful, but occasionally the splenic pain may be severe (due to perisplenitis), when hot fomentations will relieve it if it is thought necessary to use them.

Hyperpyrexia must be treated by cold sponging—if possible, with ice; if not, with the mixture mentioned above, or by cold packs, cold baths, and cold enemata.

Algidity requires special treatment with hypodermic saline injections and warm applications to the body, and especially to the region of the heart. The saline injections consist of sterile normal saline solution, and are injected by gravity from the ordinary glass reservoir via a long piece of indiarubber tubing and a stout hollow needle, such as those in the Potain's aspirator-case. The usual sites for the injection are the sides of the chest, just below the armpit, and the outer aspect of the thighs. At least a pint should be injected in one place. Oxygen inhalations, if available, may also be used. Diaphoretic pernicious fever requires stimulants, hypodermics of atrophine, and ether or strychnine, and treatment as for algidity.

Hæmorrhagic perniciosa may be treated with calcium chloride, and with local applications or injections of adrenalin. Scarlatiniform perniciosa obviously calls for dilution of the toxins by saline injections. In pernicious cases, when the patient becomes delirious or comatose, the practitioner must be careful that the attendants in whose charge he is left are really trustworthy, as unfortunate accidents have been known to happen. Particularly we warn the practitioner to make sure that the bladder has been emptied, especially in delirious patients, not by mere casual inquiry, but by percussion of the abdomen. In choleraic perniciosa the treatment for cholera should be adopted in addition to quinine. In dysenteric perniciosa the treatment must be that suggested for mild dysentery, and, in addition, quinine, while the pseudo-Addison's disease is best treated in our experience by 10 minims of adrenalin, given twice daily in addition to quinine.

Diet.—During the attack the strength must be maintained by light food, such as Brand's essence or chicken-broth, and stimulants, in the form of brandy or champagne, may be required. Milk or whey may also be given, and in cases of stomach irritation albumin water.

During remissions broths and clear soups and milk-puddings should be allowed. In the intermission of a quartan or tertian, and during convalescence, regular meals of good plain food, may be given.

Treatment of Convalescence.—The important point to be remembered in convalescence is to continue the quinine. The patient should be placed on a tonic with iron and arsenic in some form, and if he has been seriously ill he must have a change to a colder climate. The patient must be impressed with the fact that he must not discontinue the quinine on arriving in a cooler climate, as an attack of fever will surely take place if he does so.

Treatment of Chronic Malaria.—If a person is constantly suffering from attacks of malarial fever, he should be sent, whenever possible, for a change to a cooler climate in the hills or to the temperate zone, but should, of course, continue the quinine treatment. If he cannot afford a change of climate, he must be placed in bed and given rest from work, and a course of quinine therapy by intra-muscular injections carried through.

Treatment of Malarial Cachexia.—The most important feature, in addition to quinine treatment, is to send the malarial cachetic for a change of climate, as mentioned above, and treat the anæmia with iron and arsenic. A course of injections of cacodylate of quinine is often useful.

Prophylaxis.

In order that a disease may be scientifically prevented, a thorough knowledge of its etiology must be acquired and disseminated not merely among medical men, but also among the public. We know that malaria depends upon—

1. The presence of numerous human beings infected with male and female gametocytes.
2. The presence of numerous Anophelines in which the gametocytes are capable of developing into sporozoites.
3. Free access of these Anophelines to the infected human beings.
4. Air-temperatures suitable for the development of the malarial parasite in man and Anophelines.
5. Free access of infected Anophelines to non-immune human beings.

To summarize, there are three factors: (1) The human being; (2) the Anopheline; (3) the air-temperature.

In the tropics this third factor is in favour of malaria, and it cannot be altered; therefore methods of prophylaxis must be devoted to the human being and the Anopheline.

The Human Being.—The preliminary step with regard to the human being is to ask his intelligent assistance, and for this purpose education with regard to disease in general and malaria in particular is required. First of all it was necessary to bring the medical profession into touch with the discoveries made by Manson, Ross, and Grassi, and this has been done. Secondly, it was and is necessary, by lantern lectures, illustrated pamphlets, etc., to bring home to the conviction of the educated public of the tropics the monetary loss caused to the Government, the planter, the merchant —*i.e.*, to the employer of labour—by malaria. Unless this can be done, the money necessary for the effective prophylaxis will not be forthcoming. No one will deny that malaria is the greatest cause of sickness in the tropics, though there may be places where its mortality is low and places where it is high; but that which people fail to recognize is the financial loss caused by this sickness.

Therefore we quote the well-known example of the Adriatic Railway Company, which, according to Ricchi, used to spend on account of malaria among 6,416 workmen living in malarious areas no less than 1,050,000 francs per annum.

But a serious attempt should be made to impress the uneducated masses of the tropics with some sort of knowledge about the disease. This can best be done by simple kindergarten-like instruction, with demonstration of actual living specimens of *Anopheles* and their eggs, larvæ, and pupæ, together with the presence of a young child with a huge spleen and of a person suffering from malarial cachexia, and then at the close of the lecture, distribution of illustrative pamphlets in the vernacular, written in simple language, reviewing the subject of the lecture, together with, if possible, the demonstration of the larvæ in a neighbouring stream or pool.

This attempt to instruct the lower classes of the tropics may not be productive of much immediate good, but it may bring home to them that malaria is a potent factor in causing illness and death among their infants and young children, and that it is caused by the bite of a particular kind of insect, and can be to a great extent prevented by proper treatment with quinine.

Another method employed is to give the teachers of the elementary vernacular schools a course of instruction in elementary hygiene, including, of course, malaria, so that they may be able to give their pupils elementary instruction in these matters.

In such instruction no pamphlet or book should be used, otherwise there is a danger of the knowledge being acquired by rote. The only way, however, to bring about any result by this method is to award a special grant to the school, based upon the knowledge of the scholars.

All these methods have actually been and are being carried out, but in any case they are only preliminaries, and any good which may result therefrom will not be immediate.

Another preliminary matter is to use the knowledge acquired concerning the life-history of the Anophelines, and not to build houses, coolie-lines, etc., in ravines and valleys, or on the margin of water likely to be a breeding-ground for these insects. Place the buildings on high ground, and, bearing in mind the fact that native children harbour gametocytes, build the better-class houses away from the lower-class native town or village.

Leaving now these preliminaries, we come to the actual question of prophylaxis by reducing the malaria in man by quinine administration, as recommended by Koch, Celli, Plehn, Negri, and others.

Koch's method consists in taking a large dose (15 grains) of quinine on two consecutive days every eight or ten days, while Celli's method consists in taking about 6 grains (0·40 gramme) of quinine daily; Plehn's, in taking 8 grains of quinine every fourth day. Our own method is to give 5 grains daily, and, in addition, a double dose (10 grains) once a week; and in order to enable the patient to remember the routine, we advise him to take the double dose on a Sunday. For children 1 grain of quinine may be given for every three years of age, or euquinine may be used with advantage in doses of 2 to 5 grains daily. It is not very bitter, and may be given with a little sweetened condensed milk, as advised by Watson, or chocolates of tannate of quinine (2 to 5 grains), as advised by Celli, may be given.

All these methods, if properly carried out, give good results, but it must be remembered that unpleasant symptoms may arise after a long use of quinine, of which the most frequent in our experience is a tremor of the hands; but various other nervous symptoms may appear—*e.g.*, irritability.

The advantages of quinine prophylaxis are, however, in excess of its disadvantages, and we strongly recommend its use. In Italy special laws have been passed, due to the efforts of Celli, which render quinine prophylaxis practicable among the poorer classes. The quinine is manufactured by the State and distributed gratis to the poor, while employers of labour are compelled to supply it to their work-people. Governments, municipalities, etc., can also help in this way by giving free quinine to the populace.

The systematic free distribution of quinine powders, tinted if necessary, and enclosed in papers, with a vernacular label informing the recipient that there is no charge, is also useful among the native population, as is the distribution of quinine to children in the schools by the teachers. It is, however, necessary to see that the quinine is actually taken. The distribution must be carried out by itinerary dispensers, for the native will not travel far to obtain quinine.

By this method Koch freed Stephansort, in New Guinea, from malaria, but there is a doubt as to whether the disease will not recur if this method alone is used. It must be remembered that free quinine distribution on a large scale is very costly.

The next method is to prevent man from being bitten by Anophelines. This may be effected by the constant and intelligent use of the mosquito-curtain ; by rendering the dwelling, or certain portions of it, gnat-proof ; or by the application of chemicals which will keep the mosquitoes away.

Firstly, with regard to the mosquito-curtain, the mesh must be suitable—*i.e.*, twenty to twenty-four meshes to the square inch. It should be tightly spread over the bed by means of the mosquito-curtain railings of the bed, and be tucked in under the mattress. On no consideration whatever must it be allowed to hang loosely or to fall on to the ground. It should be in position in the early afternoon, and must be in good repair, for if it is torn it is worse than useless, becoming a mosquito-trap. It must be kept clean, especially at the top, which is apt to accumulate all sorts of queer things from the roof. Never travel into a malarious region without your own net, as the condition of those in rest-houses may be far from good.

Secondly, with regard to gnat-proof rooms or houses, these can be easily constructed at but slight cost by using wire-netting of twenty to twenty-four meshes to the inch, preferably the latter. Rooms and verandas enclosed in this way are a great convenience, preventing not merely molestation from mosquitoes, but also from other insects.

The Irrigation Department of Ceylon possesses movable mosquito-proof rooms, which its engineers can take with them as their work requires. These are constructed of a wooden framework, supporting the gauze, and have a double door. They are only 12 feet by 12 feet by 8 feet, and can therefore be erected inside the room of a native house if desired, or on a veranda. The cost is small.

Hospital wards ought certainly to be rendered gnat-proof in malarious districts, as persons are often found in the wards with their blood teeming with gametocytes. Hence, if there are any suitable Anophelines in the hospital, the chance of future patients suffering from other diseases becoming infected is considerable.

With regard to coolies, the third method has been tried to a certain extent with success—viz., that of rubbing all over the body an oil composed of 1½ parts of citronella oil, 1 part of kerosene, and 2 parts of cocoanut oil, to which 1 per cent. of carbolic acid is added. Coolies seem to like this mixture, which is called the 'bamber-green oil.'

Electric fans and punkahs are secondary methods of preventing Anophelines from biting human beings.

The Anophelines.—It has already been indicated that it is not necessary to exterminate the Anophelines in order to prevent malaria, but that all that is needful is to reduce their numbers. The objection has been raised to Anopheline destruction that as fast as they are destroyed in a given area others will immigrate into that place from surrounding areas.

Ross has rather aptly answered that objection by pointing out that if the human birth-rate in a place was suppressed without attracting special immigration, the population would soon decrease, and Professor Pearson, on conjectural bases, has shown that if mosquito propagation is suppressed within the circular area of a mile, the mosquito density at the centre will be 3 per cent., a quarter of a mile from the centre 18 per cent., and at the periphery 75 per cent. of the density surrounding that area. A square one mile wide will have a central density of 2 per cent., at a quarter of a mile from the boundary 11 per cent., and at the boundary 50 per cent. of the surrounding density. No experiments have, however, been carried out to determine whether these assumptions are correct.

There is, however, no doubt that Anopheline reduction leads to the reduction of malaria. The work done under Ross's direction at Ismailia proves this, for the cases of malaria were reduced from 1,551 in 1902 to 37 in 1905, and these latter were all relapses. The cost of this is given as 50,000 francs for drainage and filling up of pools, with a yearly expenditure of 18,300 francs, which worked out at 2·3 francs per head of population.

Travers and Watson at Klang and Port Swettenham, in the Malay States, by similar methods reduced the cases of malaria admitted into the hospitals from 610 in 1901 to 23 in 1905, while the cases from the surrounding district in which no antimalarial methods were employed were 197 in 1901 and 353 in 1905. The children found infected in the two towns in 1905 amounted to 0·5 per cent. of those examined, while in the surrounding district they were more than 23 per cent. The financial saving is also shown by the fact that Government employés in 1901 obtained 236 sick certificates, amounting to 1,026 days' leave, and in 1905 only 4, amounting to 30 days' leave. The cost to the end of 1905 was £10,100, with a yearly expenditure of £410. The cost up to the end of 1905 worked out at £1 4s. per head of the population.

Similar work has been done in Hong Kong by Dr. Thompson.

In Panama, under American rule, the measures taken are very elaborate and systematic, because the sanitarian is given a free hand, and economy is not considered where health is in question, with the result that malaria and yellow fever have disappeared. There can therefore be no doubt that the destruction of Anophelines will lead to the diminution of malaria.

The measures which are used may be classified into those directed against the insect and those against the larvæ. With regard to the insects, fumigation with some substance such as sulphur or pyrethrum will stupefy them and cause them to fall to the ground, when they can be swept up and burnt. This is useful in dealing with individual houses prior to residing therein.

It is, however, against the larvæ that measures are most easily taken, and these include:

Engineering Works.—(1) Draining swamps; (2) draining roads; and (3) filling in hollows.

Sanitary Works.—(1) Removal of small collections of water; (2) oiling collections of water with kerosene by means of sprays every ten days; (3) screening wells, cisterns, etc., with wire gauze; (4) removal of plants likely to contain water and act as breeding-places (the following may be specially noted: bamboos, pineapples, travellers' palms, fibre plants); (5) introduction of fish, especially 'millions,' into collections of water; and (6) growth of weed in water, especially *Lemna*, the duckweed.

Every district must be considered separately, and a systematic malarial survey having been made, those methods should be applied which seem most adapted for success. A combination of methods must be better than any one individual method. In any case, a definite scheme should be devised, and thoroughly and continuously carried out. But a word of caution is necessary. Having made the survey and estimated the cost, firstly, leave a good margin for contingencies, and, secondly, on no consideration attempt the work unless an adequate supply of money is provided, for failure is sure to result if the scheme is only half carried out.

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CHAPTER XXIV

BLACKWATER FEVER

Definition—History—Climatology—Ætiology—Pathology—Symptomatology—Diagnosis—Prognosis—Treatment—Prophylaxis—References.

Synonyms.—Malarial Hæmoglobinuric fever, Bilious Hæmoglobinuric fever, Bilious Remittent fever, Malignant Bilious fever, Hæmorrhagic Malarial fever, Fièvre Bilieuse Hématurique, Fièvre Bilieuse Hémoglobinurique, Fièvre Bilieuse Grave, Fièvre Bilieuse Mélanurique, Fièvre Jaune des Créoles ou des Acclimatés (French), Gallenfieber, Schwarzwasserfieber (German), Febbre emoglobinure (Italian).

Definition.—An acute specific fever, characterized by great blood destruction and hæmoglobinuria.

History.—The knowledge of this fever is recent, for it does not appear to have been noted by Torti, the celebrated writer on pernicious fevers, nor by his predecessors, and the first information of its existence appears to have been given by the French naval surgeons Lebeau, Daullé, and Le Roy de Méricourt in 1850-53, who drew attention to the disease in Madagascar and Nossi-Bé, after which it is mentioned as occurring in Senegal, Cayenne, and the Antilles. In 1858 Verratas described its occurrence in Greece, and in 1859 Cummings met with it in America.

The clinical signs were carefully described by Dutroulau in 1858; by Corre in 1861, who showed that the colour of the urine was due to hæmoglobin, and not to bile or blood, as had been thought; by Barthélemy and Benoît in 1865; Bérenger-Féraud in 1874 (in which year Tomaselli first described it in Italy); Pellarin in 1876; and O'Neill in 1882. Kelsch and Kiener in 1889 gave an excellent description, together with a history of the disease up to that date. In 1890 Schelling met with it in Kaiser Wilhelm's Land, and Grocco and Cardapelli in Italy, after which a series of papers by Mahly, Easmon, Eyles, and Papafio appeared on the disease, as seen on the Gold Coast, where it is called 'attridi assara,' which means bilious fever. The name 'blackwater fever,' now universally adopted, was, as far as we know, first used by Easmon.

More recently researches have been made as to its nature and treatment by Koch, Plehn, Crosse, Prout, Stephens, Christophers, Bentley, Barratt, Yorke, and others.

Climatology.—The disease occurs most commonly in tropical Africa and in certain localities in India, but it has also been reported from many parts of the tropics.

In Europe it is found in South Italy, Sicily, Sardinia, Greece, and Southern Russia. In Africa it occurs in Algeria, and through the whole of the tropical area of West, Central, and East Africa. In Asia it is well known in India, especially in the Duars, the Terai, Assam, the Jeypore district of Madras, and the Canara district of Bombay. It is also found in China, Cochin China, and Farther India. In America cases have been recorded in the southern regions of the United States, in Central and South America—especially Brazil—and the West Indies. It is not known in Egypt and Ceylon, and there are many other parts of the tropics from which it has not been reported.

Ætiology.—As usual, when no certain knowledge of the ætiology of a disease has been obtained, there are many theories. The first is the malarial theory ; the second the quinine theory ; the third, that it is a combination of malaria with some other factor ; and the fourth, that the actual causal agent is unknown.

1. *Malarial Theory.*—All the older writers attributed blackwater fever to malaria, for the following reasons :

(1) It exists wherever there is severe malaria, and is not found where this is absent. The classical reference is to the disease in South Italy, where malaria causes a mortality of 7 to 10 per 1,000, and blackwater is common, and North Italy, where the malarial mortality is 1 per 10,000, and blackwater is rare.

(2) The people attacked have always suffered from malarial fever, generally having had several attacks.

(3) According to Stephens, the blood examined the day before the hæmoglobinuria appears contains malarial parasites in 95·6 per cent. of the cases ; while on the day of the attack only 61·9 per cent., and on the day after the attack only 17·1 per cent. were similarly affected.

(4) If the parasites of malaria cannot be found, hæmozoin can be seen in the leucocytes, and an increase in the percentage of the large mononuclears noted. Thus Stephens and Christophers saw parasites in only 12·5 per cent. of their cases, but with the other two factors proved malarial infection in 93·8 per cent. The few cases in which parasites could not be found had been previously treated with quinine.

(5) De Blasi has definitely proved the presence of a hæmolysin in persons suffering from malaria.

(6) Persons attacked have usually lived a long time in the tropics.

There is not the slightest doubt that malaria causes a great destruction of red cells, and that the hæmoglobin set free in this way is manufactured into bile ; and, theoretically, it is not impossible for this conversion into bile to be incapable of coping with the hæmoglobin set free, and thus leaving a hæmoglobinæmia which becomes a hæmoglobinuria. If that be so, then every pernicious attack of malaria in which the blood is swarming with parasites ought to produce hæmoglobinuria, but this is not the case. Donovan suggests that the disease may be due to a Laverania different from *L. malariæ*.

There must, therefore, be some other factor than pure malaria to account for the disease.

2. *Quinine Theory*.—Quinine was first mentioned as a cause of blackwater fever by Verétas in Greece in 1858; next by Tomaselli in Catania in 1874; and later by Grocco and other Italian and Greek observers. More recently, Plehn and Koch have strongly supported this theory.

The facts in its favour are:

(1) There are people in whom a dose of quinine will produce hæmoglobinuria.

(2) Quinine has a slight hæmolytic power, and Koch has noted a diminution of red cells after its administration. Experimentally, hæmolysis can be produced in healthy and malarial blood.

(3) According to Marchoux, quinine in hæmoglobinuria is locked up in the tissues, and does not appear in the urine till after the attack.

There can be no doubt—and we can personally bear testimony—that quinine sulphate can, in certain people, produce hæmoglobinuria; but these are not healthy people. On the contrary, they are already suffering from malarial cachexia or chronic malaria.

3. *Malaria, together with some other Factor*.—As malaria by itself has proved rather weak ætiologically, some other factor has been brought in to support it. Thus Corre suggested chills, Bérenger-Féraud mercury, and others acute and chronic alcoholism, syphilis, severe muscular exertion, mental excitement, and change of climate.

More recently Stephens has supported the theory that the disease is malarial, aided by a second factor—viz., quinine.

In his most recent article in Osler's 'System of Medicine' Stephens sums up his view: 'Blackwater is not a disease *per se*, but rather a condition of blood in which quinine, other drugs, cold, or even exertion, may produce a sudden destruction of red cells. The condition is produced only by malaria, and generally by repeated slight attacks, insufficiently combated by quinine. In such cases of chronic malaria—*i.e.*, in those suffering from anæmia, with repeated attacks of fever and repeated doses of quinine—blackwater fever sooner or later almost certainly supervenes—at least, in tropical climates.'

These statements are too sweeping, otherwise the home of the disease would be Ceylon, whereas it is so rare that we have never heard of a genuine non-imported case; for in this island there are Europeans and natives with just the conditions required by Stephens, and yet they do not develop blackwater fever.

On the other hand, a man comes to Ceylon from Africa and quickly develops blackwater, and dies, while another man from Africa, clearly suffering from chronic malaria, assures you that he has blackwater after every dose of quinine.

Stephens accounts for the difference between India and Africa as regards blackwater fever by the common malarial parasite being the tertian in India and the subtertian in Africa. Certainly the tertian is very common in Ceylon, though the subtertian is also frequently found. There is no doubt about the fact that quinine can cause hæmoglobinuria in people infected with malaria, but the connection between the two requires to be explained. According to M'Cay, who has carefully investigated the action of quinine in causing hæmoglobinuria, sulphuric acid and the sulphates cause a decrease in the total inorganic salts of the plasma, which he thinks implies a decrease in its osmotic tension. Water, therefore, passes into the red cells, causing them to swell up, and, if the decrease in osmotic tension of the plasma is sufficient, to burst.

He considers that the causation of blackwater fever is threefold:

(1) Injury to the stroma of the red cell by the malarial parasite.
(2) The action of the malarial hæmolysin.
(3) The administration of sulphates.

He thinks that, though the first and second causes may bring about the disease, still quinine sulphate or any other sulphate, by its action on the plasma, is the exciting cause if the former are ineffectual. On the other hand, he finds that chlorides cause an increase of the resisting power of the erythrocytes to hæmolysis. Quinine hydrochloride, especially when combined with sodium chloride and dilute hydrochloric acid, causes usually a marked rise in the resistance. Therefore, according to him, it is not the quinine, but the sulphuric acid in the form of quinine sulphate, which produces the hæmolytic action. In addition to sulphates, M'Cay found that alkaline carbonates, compounds of alkalis with vegetal acids and potassium salts, diminished the inorganic molecules of the plasma, thus tending to help hæmolysis. We have, however, seen hæmoglobinuria following the administration of euquinine, the hydrochloride, and even the tannate of quinine. The obvious inference from these experiments would be that quinine should be administered only as the hydrochloride or bihydrochloride.

4. *Unknown Agent.*—Sir Patrick Manson, in 1893, first promulgated the theory that blackwater fever was a disease distinct from malaria, and supported this by the peculiar distribution of the disease, which is widespread in tropical Africa, and very local in India.

Sambon, in 1898, having in mind the hæmoglobinuric fevers of animals, brought forward the theory that human blackwater fever would probably be found to be a babesiasis. Up to the time of writing, however, no such parasite has been described.

The parasites which have been described are a bacillus by Yersin in the renal epithelium, which has since been shown to be the

Bacillus coli communis ; a blood parasite by F. Plehn, which he no identifies with the subtertian malarial parasite ; and a doubl contoured parasite in the red corpuscles by Fisch, which has no been confirmed.

In our opinion blackwater fever is a disease of its own, thoug we freely admit the existence of hæmoglobinuria from quinine a well as from other drugs.

Predisposing Causes.—The predisposing causes of blackwater feve appear to be first racial, second bodily. With regard to the first the immigrant European suffers more than the native race; thoug the disease also attacks natives and half-castes. This racial distinction is, therefore, probably due to some acquired or inherite immunity. It is said that a person is usually not attacked unti after residence for at least a year in the endemic area.

The second series of predisposing causes appear to be anythin which lowers the vitality of the body—cold, change of climate another disease—*e.g.*, malaria, syphilis—or certain drugs.

Pathology.—As the ætiology of the disease is uncertain, the pathogenesis is also little understood. Working on the theory that the disease is of malarial origin, Christophers and Bentley have brought forward an explanation of the pathology. Their views may be summarized as follows :

Laverania malariæ, the subtertian parasite, acts upon the endothelial cells of the blood capillaries of various organs, but especially upon those of the spleen and liver, stimulating them to excessive destruction (erythrokatalysis) of red blood cells by phagocytosis.

This phagocytosis results in the production of an auto-hæmolysin of the nature of a hæmolytic amboceptor, which is retained in the endothelial cells until set free by some exciting cause, which may be a chill, overexertion, etc. The result of this excitation is to suddenly set free in quantity this hæmolysin, which destroys the red cells by solution in the plasma (lysæmia), principally in the blood of the liver and kidney, and to a less extent in that of the spleen.

The lysæmia produces hæmoglobinæmia, which is best demonstrated by receiving the blood into hypertonic citrate solution, and then centrifugalizing, when the serum is observed to be of an orange, rarely of a reddish, colour. The amount of hæmoglobin present in this condition was estimated by Christophers and Bentley to be from 1 to 3·75 per cent. of that present in normal blood. This hæmoglobin quickly appears in the urine as oxyhæmoglobin, which may become methæmoglobin on standing. All the hæmoglobin probably does not escape by the kidney, for there is evidence of increased production of bile, and it is possible that only such quantity as the liver is incapable of converting into bile appears in the urine. It is, however, by no means certain whether the pigment escapes only by the glomeruli or through the tubules, or by both, and it is also uncertain whether the hæmoglobin can pass through the cells of a normal kidney.

Morbid Anatomy.—There are three cardinal features in the morbid anatomy of a case which has died during hæmoglobinuria, and these are: (1) Jaundice of the tissues; (2) liquid blood; (3) swollen congested kidneys. In addition, there will generally be the signs of acute or chronic malaria in the liver, spleen, and bone-marrow.

On making the post-mortem, the yellow staining of the skin and organs is most marked. The kidneys are enlarged, dark red to black in colour, while microscopically they show degeneration of the epithelium of the convoluted and other tubules, the lumen of which is filled with granular material, while the glomeruli may contain granular material, and show desquamated capsular cells.

The liver is enlarged, and the gall-bladder full of inspissated bile. Microscopically, areas of necrosis, with thrombi in the sublobular veins and quantities of hæmosiderin in the cells, many of which may be in a state of fatty degeneration, are to be seen.

The stomach and small intestine is often hyperæmic, and the bone-marrow is yellowish, and either fluid or gelatinous.

The Blood.—The blood is thin and watery; and there may be hæmoglobinæmia and cholæmia, with lessened tonicity. The red cells and hæmoglobin are greatly reduced, and the former may include shadow cells and small fragments of cells, and deep staining round cells (spherocytes) in the early stages, and later may show degenerative changes such as polychromatophilia and basophilia, while megaloblasts and normoblasts are present. Malarial parasites or pigment may be seen.

During the fever there is marked leucocytosis, with great polymorphonuclear increase, but when the fever disappears there is leucopænia, with a mononuclear increase.

The Urine.—The urine is dark red to brownish yellow in colour, becoming sometimes black, like stout, the reddish tinge not being seen until it is diluted, and shows with the spectroscope the absorption of bands of oxy- or methæmoglobin—the latter only if the urine has stood some time. The reaction is faintly alkaline, and the specific gravity is often less than normal. A considerable amount of sediment falls when the urine is left to stand. This sediment is composed of dark-brown granular material, which is the débris of the broken-down red cells, very few of which remain intact. Hæmatoidin crystals are sometimes met with. On boiling the urine, and then allowing it to stand for some time, a bright purple colour develops (Plehn's reaction). If some of the urine is made alkaline with potash and then boiled, a purple colour, due to hæmochromogen, is produced (Stephens and Christophers' reaction). The urine resists decomposition for some time.

The presence of urobilin can be detected by acidulating with a little acetic acid, extracting with amyl alcohol, and examining with a spectroscope, when a broad band to the red side of F. will be seen. Bile pigments are seldom present, and may be recognized by Gmelin's or Maréchal's reactions. There is a considerable amount of albumin present in the form of serum albumin, serum globulin, and nucleo albumin. Phosphates are said to be diminished. The hæmosozic value is higher than that of the red corpuscles of the blood.

Symptomatology.—Usually the patient has resided six months or longer in one of the regions mentioned above, and naturally has had attacks of malarial fever, and has taken quinine.

Prodromata.—Prodromata may be almost entirely absent, but usually the patient complains of lassitude, pains all over the body loss of appetite, restlessness at night, and an entire lack of energy during the day, and a yellowish tinge may be noted in the conjunctivæ or skin for a day or so.

Attack.—Suddenly the patient feels chilly, and shivering fits may occur, accompanied by headache, severe pains in the back and legs, and an intense feeling of weakness and nausea, which, as a rule, quickly ends in retching and then vomiting, first of food, and then of green bile. The tongue is coated with a dirty-yellowish fur, and there is much thirst and constipation, the fæces at first being dark-coloured, and often scybalous.

The liver and spleen are enlarged and tender ; the skin is hot and dry, and if not already tinged yellow, rapidly becomes so, deepening in tint as time goes on. It is said that itching is sometimes felt, but we have never noted this. The conjunctivæ are tinged yellow, like the skin. The temperature rises quickly to 103° or 104° F., and the pulse is regular, rapid, small, and compressible. At first the urine may appear normal, but sooner or later the characteristic stout-like colour appears, with pains in the back and burning sensations in the urethra. On the other hand, this may be the first feature of the attack, and causes the patient to send at once for the doctor, though he may not at the time feel ill, or it may occur at the height of the fever, as Kelsch points out.

The mind may be clear or the patient may be brought to the hospital quite unconscious, and may remain so for days, or delirium may set in. After a few hours' perspiration appears, and the temperature remits to about 100° F., the urine clears, and a mild case may recover, while in a severe case, instead of the remission hyperpyrexia, coma, and death may ensue.

Usually, however, after the remission the temperature again rises (Daniel's post-hæmoglobinuric fever), and the shiverings, vomitings and pains return, while diarrhœa, with motions full of bile, and sometimes also with blood or hæmoglobin, comes on. A motion with hæmoglobin may present a most striking appearance, being mainly green in colour, with a reddish deposit on the surface.

This second paroxysm may be the last, or it may be succeeded by several others, after which the patient may recover On the other hand, he may die during these attacks from exhaustion, or from hyperpyrexia and coma, or from anuria and uræmia.

After the attacks the patient is exceedingly weak, and con valescence is protracted, and is liable to be complicated at any tim with anuria, leading to fatal uræmia.

Varieties.—Kelsch and Kiener recognize two distinct types— mild and a severe—of which the latter is subdivided into three– viz., the ordinary severe, a fulminating with a rapidly fatal issu and a uræmic type.

Complications.—The most usual complication is the passage c hæmoglobin or blood *per anum*, giving rise to ' dysenteric motions, as they are often called. Inflammation of the tonsils and salivar glands has been noted.

Sequelæ.—There is nearly always grave anæmia and much weakness as the result of an attack, with often stomach and intestina derangements, but of all, the most serious is nephritis, leading t uræmia.

Diagnosis.—Blackwater fever is easily recognized, as a rule, an the only disease with which it could be confounded is yellow feve in which, however, there is never hæmoglobinuria. Acute yello atrophy of the liver and Weil's disease are easily distinguished b the urine.

Prognosis.—The mortality in our experience varies greatly, bein very high in some epidemics and low in others. The mortalitie given by Skelton are as follows: F. Plehn, 4 per cent.; A. Plehn 6·8 per cent.; Stendel, 16 to 17 per cent.; Koch, 21 per cent. Bérenger-Féraud, 23 to 24 per cent.; Schellong, 42 per cent. Reynolds, 50 per cent.

Bad signs are:

1. Persistent vomiting.
2. Hiccough.
3. Profuse diarrhœa.
4. High fever.
5. Sudden decrease in the tension and increase in the frequency of the pulse.
6. Diminution or cessation of urine.
7. Coma.

Good signs are:

1. Little gastro-intestinal disturbance.
2. Low temperature.
3. Good pulse.
4. Clear mind.

It is usually said that a person should not return to the tropic after suffering from blackwater fever, but many people do return and appear to remain in excellent health. Of course, there is th great risk of further attacks.

Treatment.—In treating the disease, the important features to b remembered are that the patients are generally infected wit malaria; that they suffer from a great blood destruction, and therefore from great weakness; that, as a result of the blood destruction a severe strain is thrown on the liver and kidneys; and that th latter are apt to be damaged by the hæmoglobin. In fact, som people think that the hæmolysis takes place in the kidney, but i any case there is danger of blocking of the renal tubules, of nephritis anuria, and uræmia. Lastly, the disease is apt to relapse.

From the very commencement, no matter how mild the symptom may be, the patient must be put to rest in bed, and have carefu nursing. Another most important matter is to flush out th kidneys, and this should be done by getting water into the system in some way. If the patient can take liquids by the mouth, us Sauerbrunnen, soda-water, albumin-water, whey, cold or warm tea barley-water, or toast-water, in quantity.

If the vomiting is such that liquids are not retained, try salin injections by the rectum, and if this cannot be done because o diarrhœa, use saline subcutaneous injections as described i malaria. It is also most necessary to keep up the heart's actio and the blood-pressure, and since 1897 we have used hypodermi injections of digitalin, and at times also of ergotin, for this purpose The digitalin also helps the renal secretion.

The condition of the stomach, liver, and kidneys may counterindicate stimulants at times, but there is no doubt of the value o champagne and brandy when it can be administered. Chlorides, i the form of sodium chloride or, better, calcium chloride, should b given, in order to increase the tonicity of the blood. Calcium chloride may be given in doses of gr. xv. to xxx., well diluted, every four hours, but care must be taken not to prolong the administration more than a few days. In bad cases Billet recommends subcutaneous injections of 100 to 200 c.c. of the following mixture :

Calcium chloride	4 to 5 grammes,
Sodium chloride	10 grammes,
Distilled water	1,000 grammes,

two or three times in the twenty-four hours.

Calcium chloride has a tonic effect on the heart, and acts also o the renal cells, and is therefore very suitable for the treatment o this disease.

If malarial parasites are found in the blood, they should be treate by intramuscular injections of quinine bihydrochloride, but n sulphate or bisulphate of quinine should be administered. I quinine be administered by the mouth, the tannate is the mos suitable preparation. It is advisable to give the quinine according to Nocht's method—that is to say, in minute doses (2½ grains often repeated.

The vomiting should be treated as in malaria, and constipation with calomel and enemata.

The pain in the back caused by the irritated kidneys when hæmoglobinuria is taking place may be relieved by fomentations, or, i necessary, by a hypodermic injection of morphia, which, indeed relieves many symptoms. If anuria sets in, the skin must b made to act by vapour baths before which a hypodermic o pilocarpine may be given, or by cupping over the kidneys, and fr purgation.

Headache may be relieved by cool applications to the head.

Dr. O'Sullivan-Beare strongly recommends the decoction or the flu extract of the root of *Cassia bearcana* Holmes ; the latter can be obtain from T. Christy and Sons, Old Swan Lane, Upper Thames Street, Londo and should be administered in 1 fluid drachm, well diluted with water, eve two hours at first, and afterwards at longer intervals. We have no expe ence of this drug, but its introducer praises it highly, stating that it reliev all the symptoms quickly. Skelton says he has never seen it do any goo but that it does no harm.

So well is the disease known in West Africa that several native remedi exist.

With regard to other drugs, atoxyl is said to be useless. Cautley has us turpentine in mild attacks.

min Hearnsey has recommended liquor hydrargyri perchlori ~~gr.~~ xxx., sodii bicarbonate gr. x., every two or four hours.

Diet.—The diet must be fluid, preferably in the form of whe milk, chicken broth, albumin-water, and Benger's food ; but stro meat-extracts should be avoided.

If the vomiting is troublesome, and there is no diarrhœa, rect feeding might be tried. Plenty of aerated water should be allowe

Climate.—A patient will require a change to a temperate clima in order to recuperate after a severe attack.

Prophylaxis.—Very little can be said with regard to the proph laxis, as the knowledge of the ætiology is incomplete. As blac water fever generally develops in persons who have suffered fro malaria, quinine prophylaxis should be carried out in the mann already described in the chapter on Malaria, attacks of mala being treated by quinine tannate in small repeated doses, or t drug should be preceded by a dose of calcium chloride.

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CHAPTER XXV

THE RELAPSING FEVERS

The relapsing fevers—The relapsing fever of Europe—The relapsing fever of America—The relapsing fever of India—The relapsing fever of Africa—References.

THE term 'relapsing fever' includes several diseases caused by different spirochætes—for example, the European relapsing fever is caused by *Spirochæta recurrentis*, the American by *S. novyi*, the African by *S. duttoni*, while that in India is due to *S. carteri*. The relapsing fever of Egypt appears to us to require further investigation with reference to whether the disease is caused by *S. recurrentis* or by some other variety, and the same remark holds good for the Southern China and South American relapsing fevers. We therefore recognize at present four principal types of relapsing fever —viz. :

The relapsing fever of Europe ;
,, ,, America ;
,, ,, India ;
,, ,, Africa ;

but we are not certain that other types may not be differentiated later, as Fränkel has apparently done recently with regard to an East African type.

Marchoux, in drawing attention to the loss of virulence in *S. marchouxi*, when passed directly through a succession of fowls, points out that in nature this virulence is maintained by passage through the tick *Argas persicus*, and he suggests that there may be a common type for all the blood spirochætes, which may be merely varieties whose pathogenic powers have been fixed by being transmitted by various arthropods. Hence, perhaps, the variations seen in the Spirochætæ of relapsing fever in man.

THE RELAPSING FEVER OF EUROPE.

Synonyms—*English.*—Febris Recurrens, Five Days' fever, Spirillum fever, Five Days' fever with relapses, Typhus Recurrens, Seven Days' fever (not Rogers'), Icteric Typhus, Remittent fever, Bilious Typhoid, Epidemic Remittent fever, Miliary fever, Relapsing fever. *French.*—Fièvre à Rechute. *German.*—Rückfallfieber, Die Hungerpeste. *Italian.*—Febbre Ricorrente. *Egyptian.*—Homa el Hugga, Homa el Naxy, Naushah.

Definition.—An acute specific relapsing fever, caused by *Spirochæta recurrentis* Lebert 1874, and perhaps spread by some blood-sucking animal—possibly by *Cimex lectularius* Linnæus.

History.—Hippocrates was the first writer to describe an epidemic of relapsing fever in Thasos, but this knowledge was entirely lost, and the reference was not understood until after relapsing fever was properly defined. Strother and other observers refer to fevers with relapses in London and in Ireland in the eighteenth century, and the surgeons of Napoleon's army in Egypt recognized a fever with recurrences. In 1826-27 there was an epidemic of fever in the United Kingdom, during which it was recognized that there were two distinct types of typhus—viz., a mild and a severe. In 1842 this mild type again appeared in Scotland, and, to a lesser extent, in England, and continued in the years 1843, 1846, and 1847. In 1843 Henderson, of Edinburgh, defined this mild type as a fever distinct from typhus. About the same time it was recognized in Germany, and later by Griesinger (1851) in Egypt as bilious typhoid, and somewhat later in Russia.

In 1868 there was an epidemic in Berlin, when Obermeyer, one of Virchow's assistants, first saw a spirochæte in the blood of a patient; but he does not appear to have been very certain about this at the time, for he waited till the next epidemic in 1872, and even then did not publish his account till 1873. This spirochæte was named *S. recurrens* by Lebert in 1874, and *S. obermeyeri* by Cohn in 1875, and was proved by Münch, of Moscow, to be the cause of the disease by the successful inoculation of blood containing the spirochætes into healthy human beings—an experiment which has since often been repeated accidentally at post-mortems. It has been inoculated with success by Metchnikoff and others into monkeys and mice. In 1888 Sakharoff suggested that this organism was a protozoon—a view which increasing knowledge tends to support.

In Russia, where the disease has been well known since 1863, there is a popular belief that it is spread by the bed-bug *Cimex lectularius* L., which belief was supported by Flügge in 1891. In 1897 Tictin found that he could infect monkeys by inoculation of the blood obtained by crushing bugs which had very recently been fed on a patient—*i.e.*, within forty-eight hours.

Spirochætes have been found in bugs during relapsing fever epidemics by Karlinski in 1902, and later by Schaudinn. Nuttall has successfully transmitted *S. recurrentis* from mouse to mouse by the bites of bugs. Dönitz's hypothesis, that *S. recurrentis* is conveyed by ticks, has not been supported by experiments.

Climatology.—The disease is endemic in Russia, Ireland, Turkey, Denmark, Norway, Bohemia, and in some parts of Poland and Germany, while the same or a similar type is found in Lower Egypt, in Southern China, and perhaps in the Philippines. There, however, appears to be some doubt about the presence of the disease in these islands; the authority for the statement is McCrae, in Osler's 'System of Medicine.'

Ætiology.—This type of relapsing fever is caused by *S. recurrentis* Lebert 1874, which is generally to be found in the peripheral blood during the attacks, but is usually absent in the apyrexial interval, though individuals may occasionally be found after prolonged search.

This spirochæte is carried from the sick to the healthy probably by some blood-sucker—possibly in some cases by the bed-bug *Cimex lectularius* L. It can also be spread by direct inoculations such as may take place accidentally in laboratories or at post-mortems.

Pathology.—The life-history of *S. recurrentis* is but little known, and may possibly resemble that of *S. duttoni*, which has already been described. The presence of the spirochætes in the blood is associated with fever, which must be due to toxins produced by these organisms, though the severity of the symptoms bears no relationship to the number of the organisms found in the peripheral blood. The spirochætes disappear from the circulation when the temperature falls to normal. The disappearance of the parasites from the blood is brought about by the presence of antibodies (agglutinins and parasiticidal substances). In those cases, however, in which relapses occur, the blood remains infectious during the intervals. This is due to some parasites resisting the action of the antibodies. These resistent spirochætes after a time multiply again in large numbers, giving rise to the relapse. Levaditi and Roche have demonstrated that serum collected after a first attack destroyed the spirochætes which caused the attack, but had no effect whatever on the spirochætes which caused the second attack. The relapses, therefore, are caused by the survival of resistent types of spirochætes, and recovery depends upon the existence of protective substances in the blood. The immunity acquired after one or several attacks may last for some weeks or months. Animals can be hyperimmunized by repeated inoculations after recovery from the first attack. The serum of such hyperimmunized animals shows definite protective and curative properties.

Morbid Anatomy.—The principal pathological feature of the post-mortem is the enlargement of the liver and spleen, the latter organ reaching, it is said, a weight of 1 to 2 kilogrammes. On section, the spleen is dark-coloured and soft, with enlarged follicles, and on microscopical examination shows congestion and a cellular increase. The liver is enlarged, and its lobules are poorly defined, while microscopically cloudy swelling and fatty infiltration may be seen, as well as leucocytic infiltration into the portal system. The kidneys are enlarged and congested, and microscopically show cloudy swelling and fatty degeneration of the cells, while the stomach shows signs of inflammation, and the heart is soft and flabby.

The bronchi are generally congested, and contain frothy mucus, and the lungs show hypostasis. The brain may be congested, and all the organs may be stained yellow with bile.

Symptomatology.—The incubation is said to vary between two and twelve days, but in accidental inoculations it is about seven days. During this period prodromal symptoms, in the form of slight malaise, may be felt. The onset is usually sudden, but it may be gradual, the patient suffering from rheumatic-like pains, headache, and constipation. When it begins suddenly, there are rigors, with severe frontal headache, pains in the back and limbs, epigastric pain and tenderness, associated with a sense of weakness. The face becomes flushed, the conjunctivæ injected, and the temperature rises to 103° F. to 104° F., with a pulse-rate of 110 to 120, quickened respirations, and sometimes nausea and vomiting.

The temperature continues high until the sixth or seventh day, during which period the skin is yellowish in colour, hot and damp from perspiration, with often a rose-coloured macular eruption, disappearing on pressure, on the thorax, abdomen, and legs, which lasts for a day or so. The tongue is moist, red at the tip, and covered with a white fur. Vomiting of greenish-yellow matter may occur, but nausea is always present, and thirst is common; the bowels are usually constipated, and diarrhœa is more a complication than a feature of the disease. The liver is enlarged and tender, and so is the spleen, which may reach a considerable size. The heart-sounds are normal, but the pulse-rate is quick, reaching 120 to 140, or even more, per minute; but it is not dicrotic. The erythrocytes and the hæmoglobin are reduced in amount, while a polymorphonuclear leucocytosis is present. Spirochætes can be found in the blood, and occasionally can be seen engulfed by leucocytes. There is generally a troublesome cough, with scanty bronchitic expectoration, and râles, which can be heard over the chest and trachea. The respirations follow the pulse-rate, being increased to 48 to 50 per minute if the temperature is high. The pains in the muscles and joints continue, and sleeplessness may result, while a noisy delirium is not rare, but stupor is uncommon. The urine is febrile, and may contain a little albumin. About the sixth or seventh day the crisis, sometimes ushered in by a rigor, intervenes, with violent perspiration, or diarrhœa, with or without epistaxis, and with a sudden rapid fall of temperature, while the pulse and respirations also return to normal, and the patient falls into a deep sleep, and awakens much better.

The *intermission* now begins, during which the temperature, the spleen, and liver return to normal, and the patient's strength slowly improves. The disease may now end; but this is exceptional, and more usually, about the fourteenth day from the first commencement of the illness, the *relapse* occurs, beginning with a rigor and symptoms resembling the attack, but often more severe, and, after lasting three or four days, terminating in a crisis, which generally ends the illness. Very rarely is there a second relapse, in which case the same symptoms occur, but much less severely, and a third relapse is most uncommon. Convalescence is sometimes slow.

Complications.—The complications are numerous, affecting the lungs in the form of bronchitis and pneumonia, or the alimentary canal as dysentery, diarrhœa, and hæmatemesis ; while cerebral hæmorrhage, conjunctival hæmorrhage, iritis, and corneal ulcers, have all been recorded.

Abortion often complicates the first relapse in pregnant women.

Diagnosis.—In the first instance, before the relapsing character has appeared, the disease requires to be diagnosed from malaria typhus, typhoid fever, yellow fever, and seven days' fever. The principal positive signs indicating relapsing fever are : (1) presence of the spirochætes in the blood ; (2) agglutination or Lowenthal's reaction, which consists of taking a drop of blood from the suspected case and adding it to another drop of blood containing spirochætes taken from a patient, mixing the two drops together, and covering with a cover-glass, which is then sealed and placed in an incubator at 37° C. for half an hour. A positive reaction is indicated by the clumping of the spirochætes into non-motile masses. Malaria can be diagnosed by the discovery of the malarial parasite in the blood.

Typhoid is indicated by the absence of marked leucocytosis Widal's reaction is not of much help during the first week. Typhus can be separated by the absence of spirochætes, by a negative Lowenthal's reaction, and by the presence of its characteristic rash Yellow fever can be diagnosed by its black vomit, though at first the differentiation may be impossible without a microscopical examination of the blood. Seven days' fever is characterized by its slow pulse and, of course, by the absence of spirochætes. Weil's disease may be distinguished by the more marked jaundice and by the absence of spirochætes.

Prognosis.—The prognosis is usually favourable. Marked jaundice is a bad sign, while pregnant women generally abort. The mortality appears to vary considerably, being, according to Murchison, only 4 per cent. in the United Kingdom ; while, according to Sandwith, it is 14·4 per cent. in Egypt, which is nearly the same percentage as that reached in Russia. The causes of death are toxæmia in the first attack, and collapse in the first intermission but it may be caused by one of the above-mentioned complications.

Treatment.—The treatment is symptomatic, and consists of relieving pains in the head and muscles by salicylates, aspirin antipyrin, or by quinine. If these pains are very severe, opium or a hypodermic injection of morphia may be necessary. The epigastric pain may be relieved by fomentations sprinkled with tincture of opium, while vomiting should be treated with ice champagne and bismuth mixtures, though occasionally morphia or codeine may be required. Effervescing ammonium carbonat mixtures are often grateful.

A dry, troublesome cough may be relieved by codeine or smal doses of heroin; in other cases an expectorant mixture will b found useful. Constipation must be relieved by laxatives o enemata, and high temperatures by cool sponging, which, however will but seldom be required. The complications must be met b the treatment laid down in textbooks on general medicine.

Prophylaxis.—Prophylaxis should aim at keeping biting animals such as bugs, from the patient, which may be done by furnishin hospitals with iron bedsteads, which can readily be taken to piece and cleaned, and by strict cleanliness.

THE RELAPSING FEVER OF AMERICA.

Definition.—An acute specific fever caused by *Spirochæta novyi* Schellach 1907. Mode of infection not known.

History.—Relapsing fever has been known in America for many years, being recognized as far back as 1844; but it was considered to be identical with the European type until, in 1906, an Englishman who repeatedly travelled between New York and the West Indies was treated by Carlisle in New York for fever which relapsed, and in which spirochætes were found. Novy and Knapp studied these spirochætes, and showed that they were distinct from *S. duttoni*. Later, Mackie also studied them by the agglutination method, and agreed with Novy, who had concluded, from morphological reasons, that they were distinct from *S. carteri*. Finally, in 1907, Manteufel compared them with true *S. recurrentis*, and found that the serum of a person suffering from their type of fever did not agglutinate true *S. recurrentis*. Subsequently Schellach, after studying and comparing the different spirochætes, named this particular species *S. novyi* Schellach 1907, in honour of its discoverer.

Climatology.—The disease is known in America and in Europe. In America the disease is acquired naturally. In Europe the cases recorded are due to laboratory infection.

Symptomatology.—The symptoms appear to be much the same as in the European type of fever. The incubation period seems to be at least five to seven days in duration, though cases have been recorded in which symptoms developed almost immediately after exposure to infection. In experimental cases it varied between six and eight days.

Mortality.—The mortality is not high, varying between 2 and 6 per cent.

Treatment.—The treatment is the same as in the European type.

In South ~~Africa~~ America (Colombia) a relapsing fever occurs in which the Spirochæte resembles more closely *S. duttoni* than *S. novyi*. According to Robeledo, this parasite is carried by *Ornithodoros turicatus*.

THE RELAPSING FEVER OF INDIA.

Definition.—An acute specific relapsing fever caused by *Spirochæt carteri* Manson 1907, and spread by some blood-sucker not definitel known.

History.—Relapsing fever is one of the endemic diseases of India being traceable back into the eighteenth century. The credit o first clearly defining the disease, however, rests with Lyall in th epidemic fever in the Punjaub in 1852-53; but Vandyke Carter in 1876-77, in the Bombay Presidency found spirochætes in th blood of patients suffering from fever, and his work on the subject published in 1882, is to be regarded as the Indian classic on thi fever. Schellach, in 1907, separated this spirochæte from *S. re currentis* and *S. novyi* by finding that it is not agglutinated by th serum of animals infected with these parasites. Rogers points ou that the disease has often been confounded with typhus fever ir India.

Climatology.—The real home of the disease appears to be th Bombay Presidency, but it is also known in the Punjaub and in th Kumaon Hills of the North-Western Provinces.

Ætiology.—The cause of the disease is the spirochæte found by Vandyke Carter in 1877. It is inoculable into man, as was proved by Carter inoculating himself twice, with an interval of two and a quarter years. It can also be inoculated into monkeys, but not into rats and mice. Bugs are capable of retaining it alive in their alimentary canals for from four to seven days when obtained from monkeys, but do not appear to be so effective in obtaining it from man, as only one in fifty-three were found infected after feeding on human beings. Infected bugs are capable of transmitting the disease to monkeys. Rogers, however, thinks that mosquitoes may be found to be more effective than bugs. Mackie has brought forward evidence in favour of *Pediculus corporis* being a carrier of the spirochæte.

S. carteri is separated from *S. duttoni* by the latter being far more easily inoculable into animals and producing numerous relapses when injected into monkeys, while, according to Lamb, the former only causes one relapse. Moreover, the two spirochætes may be differentiated by immunization and agglutination tests.

Pathology.—The morbid anatomy resembles that of the European type.

Symptomatology.—In accidental inoculations in the post-mortem room the incubation period varies from three and a half to seven days, during which prodromata, resembling those of the European type, may occur.

The onset is generally sudden, but in most cases without the rigors defined in Europe, though chilliness occurs, and the disease progresses as in the Obermeyer fever. On the fall of temperature to subnormal, however, on the sixth or seventh day, which is associated with profuse perspiration and polyuria, instead of the patient feeling better, he often becomes very collapsed, with a small weak pulse and a cold clammy skin, in which condition he may resemble at first sight a cholera patient. In the first intermission, which lasts from three to twelve days—generally about eight days—the patient improves slowly, there being much debility, and in one case in six there is a sudden temporary rise of temperature after the crisis. Spirochætes are not to be seen in the blood, but Carter and Pisani have described peculiar structures. The first relapse occurs about the fourteenth day of the disease, and the seventh of the intermission, and resembles the first attack, but the temperature may reach a higher level, and the illness is shorter, ending in a crisis.

The second intermission may last about ten days, being longer than the first, and a second relapse takes place, often commencing with chills. The liver does not markedly enlarge, but the spleen increases in size. The fever is remittent or intermittent, and the crisis is not marked. It is now rare for the disease not to end, but after an interval of fourteen to seventeen days a third relapse may take place, with a sudden rise of temperature, which lasts one to four days. Very rarely a fourth intermission of about eleven days ends in a fourth relapse, lasting only two days.

With regard to the frequency of the relapses, Rogers gives the following percentages :

Without relapse	23·8	per cent.
With one relapse	49·2	,,
With two relapses	20·0	,,
With three relapses	5·0	,,
With four relapses	2·0	,,

Varieties. — The typical course may be varied in about 25 per cent. of cases, and present (*a*) *a short, irregular remittent fever ;* (*b*) *a so-called bilious remittent fever,* called by Carter 'icteric fever.'

(*a*) *Short, Irregular Remittent Fever.*—This is very like malaria, from which it is only to be diagnosed by blood examination.

(*b*) *So-called Bilious Remittent Fever* (*Icteric Fever*).—So-called bilious remittent fever very closely resembles typhus fever, and to some extent yellow fever, showing deep jaundice, with an eruption of red spots. The temperature is irregular, and the pyrexia prolonged ; prostration comes on early, and may develop into a 'status typhosus.' The death-rate of these cases is high, being 70 per cent. They are to be diagnosed from typhus by the blood examination, and from yellow fever by the absence of black vomit.

Complications.—These are the same as in the European type.

Prognosis.—A prolonged, irregular first attack, ending by lysis, and attacks showing marked jaundice are bad omens.

The mortality is higher than in Obermeyer's type, being 18·02 per cent., of which about one-half take place in the attack and one-quarter in the first interval, and one-fifteenth in the firs relapse, and the remainder from complications.

Treatment.—The treatment and diet differ in no respect fron that already laid down, except that cardiac stimulants should b given during the attack, and preparation made for preventing th collapse by means of hypodermics of strychnine and ether, o camphor in ether, as well as by hot bottles, blankets, etc.

Prophylaxis.—See remarks with reference to the European type.

THE RELAPSING FEVER OF AFRICA.

Synonyms.—Tick fever (Livingstone), African Tick fever.

Definition.—An acute specific relapsing fever caused by *Spirochæt duttoni* Novy and Knapp 1906, and spread by *Ornithodoros moubat* Murray.

History.—The peoples of Africa from time immemorial have ha a dread of tick-bites, which they thought caused fever, and thi appears to have been noted by Livingstone, Kirk, Hinde, an many other people, with the result that a tick fever of an unknow nature was spoken of as occurring in Africa. Nabarro, in August 1903, was the first to observe a spirochæte in human beings i Uganda, but as his publication, through no fault of his own, di not appear till much later, his discovery was forestalled by those o Ross and Milne in 1904, and Dutton and Todd, also in 1904, wh found the cause of the tick fever to be a spirochæte, the latte observers also proving that it was introduced into the blood by th bite of a tick—*Ornithodoros moubata.* Since that date Koch Todd, Novy and Knapp, Breinl and Kinghorn, and others, hav studied the disease carefully. Recently Fränkel has proved b biological tests that the spirochæte of East African relapsing feve differs from *S. duttoni*, as observed in West Africa, and Nuttal has proposed the name *S. rossii* Nuttall 1908 for this new species.

Climatology.—The disease is found in Angola, the Congo Fre State, Uganda, and German East Africa and Portuguese Eas Africa, and in the Valley of the Zambesi. Recently Franco Robled and others have described a spirochætiasis in Colombia, which i caused by a spirochæte morphologically resembling *S. duttoni*, an said to be spread by *Ornithodoros turicatus*, with reference to which i may be noted that Büldow observed relapsing fever in the Ande in 1865.

The climatic conditions required appear to be heat and moisture but according to Franco's observations, the disease can occur at an altitude of 7,000 feet. No observations appear to be recorded a to variations due to season.

Ætiology.—The cause of the fever is *S. duttoni* Novy and Knapp 1906, which is proved to be distinct from the other spirochætes, because an animal immunized against one of these is capable o being successfully inoculated by it. *S. duttoni* can be inoculated into a number of animals—namely, dogs, goats, sheep, rabbits, guinea-pigs, rats, and mice—but not into cats, chickens, pigeons, or goldfish. The spirochætes can pass through the placenta into the circulation of the fœtus, which they infect. These organisms are easily seen in the blood during an attack, but disappear during an apyrexial interval.

The life-history in the vertebrate has been worked out by Breinl, who, as already described, showed that just before the crisis the spirochætes become encysted and undergo schizogony into small bodies, from which the new generation develop. Quite recently Leishman has demonstrated that when the spirochætes pass into the intestinal sac of the tick they lose their motility and their characteristic appearance, while the central core of chromatin segments into small masses, which are set free into the lumen of the gut. These small bodies, which resemble small rods, or are rounded, like micrococci, appear to multiply in the body of the tick, and to pass into the cells of the Malpighian tubules and into the tissue of the ovary. In the latter position they enter the immature eggs, and can be traced through all stages of development into the adult ticks. In the embryo, and in all the later stages of development up to and including the adults, they are found as small chromatin bodies lying in the cells of the Malpighian tubules. Inoculation of crushed tissue containing these bodies produces a typical infection. From his experiments, Leishman concludes that it is by these chromatin bodies that the disease is carried from the egg to the new generation of ticks, and that infection of man does not take place via the salivary glands, but by the small bodies gaining access to the wound produced by the tick's bite, by being voided in the Malpighian secretion passed by the tick during feeding, or perhaps by regurgitation of the intestinal contents.

The principal predisposing causes are anything which facilitates the life of the tick, such as bad hygienic conditions, which are well exemplified by the native huts of Africa. These huts contain many cracks in the walls and floor, which afford shelter to the tick, and hence predispose to the disease.

Pathology.—Very little can be said as to the pathology at present. The post-mortem reveals only an enlarged firm spleen, while smears taken from the liver and lungs show large numbers of spirochætes.

Symptomatology.—The symptomatology still requires careful investigation on the lines carried out by Carter in India. There appears to be a marked difference in the severity of the attack in new-comers, such as Europeans and natives, and Ross has, therefore, divided the symptomatology into two classes—(*a*) European; (*b*) Native.

SYMPTOMS IN EUROPEANS.—The period of incubation is usually about seven days, but it may extend to eleven or twelve days.

The tick-bite may be accompanied by local inflammatory symptoms, but in some cases the bite is not even noticed. According to Wellman, natives believe that when the tick-bite is accompanied by a severe local reaction, the individual probably escapes fever, and

Nuttall calls attention to the possible protective effect of a loca reaction.

Usually mental heaviness, lack of activity, profuse sweating, an constipation, are mentioned as prodromal symptoms.

The attack may come on gradually, with a feeling of malaise faintness, and a disinclination for food, or even vomiting, and slight rise of temperature. In a few hours the temperature wil have risen to 103° to 105° F., associated with headache, pains i the back and limbs, and intense pain in the region of the spleen, an chilliness. There is vomiting, first of food, and then of bile, wit often diarrhœa, and even at times streaks of blood in the motions The spleen is generally found to be enlarged, and spirochætes i scanty numbers occur in the peripheral blood, but may be hard t find.

The next day the symptoms are worse, and the patient is hot an restless, complaining of thirst and splenic pain, and often trouble by a cough. The temperature shows a morning fall, withou improvement in the symptoms, and an evening rise, during whic the pains increase, and the patient may become delirious. Th liver does not enlarge, but the spleen projects below the costa margin. Spirochætes are now found in greater numbers, bu diminish remarkably before the crisis. There is a slight decreas in the red cells and hæmoglobin, and a marked leucocytosis befor the crisis, while polychromatophile degeneration is noted in th red cells, and a very marked increase in blood platelets. Th symptoms last three to four days, and end by a crisis marked b profuse sweats and a fall of temperature below normal. On th day before the crisis there is a pseudo-crisis, with a fall of temperature, but no improvement in the symptoms.

The patient feels weak and tired, but slowly regains his appetit and strength, and no parasites are found in the blood. The disease may now terminate, or the intermission may last from one t twenty-one days, according to Ross ; but five to eight days is mor usual.

The first relapse begins with a rise of temperature and a retur of the original symptoms, and also of the parasites into the peripheral blood. After lasting three to four days, it ends in a crisis marked by sweating, and showing a pseudo-crisis on the preceding day.

Intermissions and relapses follow one another regularly o irregularly, the intervals being from one day to two months, and the relapses usually lasting three days, and showing a pseudo-crisis on the second day and a crisis on the third day. As many as five to eleven relapses may take place, and end by reducing the patient both in weight and strength. Œdema of the eyelids has been noted in the relapses.

Complications and Sequelæ.—Iritis is very frequently observed.

SYMPTOMS IN NATIVES.—Ross in Uganda and British East Africa found that though the attack showed much the same symptoms in natives as in Europeans, it was far less severe, and the spleen did not enlarge. The attack only lasted twenty-four to forty-eight hours, and ended by crisis, after which the patient rapidly recovered, as a rule without a relapse. Should this, however, take place, it was found to be less severe than the attack. Koch believes that these mild attacks and the native immunity are due to infection in early childhood. Dutton and Todd, on the other hand, describe cases very much resembling that in the European, with enlargement of the spleen, and with more than one relapse, leaving the patient anæmic, thin, and weak. Hence it may be concluded that the disease shows two types in natives—a mild type and a severe type—and that the latter may end in death; or perhaps it may be that the West African or East African fevers are separate clinical entities, and indeed there appears to be some justification in their separation, as the spirochæte of East African fever has been shown to differ biologically from that of West African.

Diagnosis.—This can only be made by finding the spirochætes. Löwenthal's method of agglutination can be applied in doubtful cases.

Prognosis. — This is usually good for both the natives and Europeans, but death may occur in both races, and is signalled by a rapid fall of temperature without improvement of the symptoms.

No figures have so far been recorded with regard to the mortality, but it may be taken that it, as a rule, is low, though under adverse circumstances it may be high. Dutton and Todd record that of twenty men who contracted the disease in one caravan, ten died.

Treatment.—Atoxyl and other arsenical preparations have been found to be useless, and only symptomatic treatment can be applied (p. 703).

Prophylaxis.—The prophylaxis is based on the avoidance of localities where ticks abound and the destruction of these parasites. Koch rightly advises that Europeans should camp at least 20 to 30 yards away from infected native huts and rest-houses.

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CHAPTER XXVI

THE SPOTTED FEVER OF THE ROCKY MOUNTAINS AND TSUTSUGAMUSHI DISEASE

The spotted fever of the Rocky Mountains—Tsutsugamushi disease—The tick fever of Miana—The intermittent tick fever of Wyoming—References.

SPOTTED FEVER OF THE ROCKY MOUNTAINS

Synonyms.—Black fever, Blue disease, Rocky Mountain Spotted fever, Spotted fever of Montana, Rocky Mountain fever, *Pyroplasmosis hominis* Wilson and Chowning 1902, Spotted fever of Idaho (Maxy, 1899), Tick fever of the Rocky Mountains (Anderson, 1903).

Definition.—An acute endemic febrile disorder, associated with a petechial or purpuric eruption of the skin, which occurs after the bites of infected ticks (*Dermacentor occidentalis*) in certain regions of the Rocky Mountains.

History.—The first case of the disease is believed to have occurred in Bitter Root Valley, in 1873, and from that date until 1902 it is said that about 200 cases were observed, with a mortality of 70 to 80 per cent. During this period it was generally known as the 'black fever,' the 'blue disease,' or the 'spotted fever.'

In 1898, according to Anderson, Major M. W. Wood made an unpublished report to the Surgeon-General of the United States army on the disease. In 1899 Maxy wrote a paper on 'The So-called Spotted Fever of Idaho,' which he described as an acute, endemic, non-contagious, but probably infectious febrile disorder, characterized clinically by a continuous, moderately high fever, severe arthritic and muscular pains, and a profuse petechial or purpuric eruption of the skin, appearing first on the ankles, wrists, and forehead, but rapidly spreading to all parts of the body. In 1902 Gwim and McCullough read separate papers on the disease at a meeting of the Montana State Medical Association, and in the same year Wilson and Chowning were deputed to investigate it in the Bitter Root Valley. As a result of their investigation, they concluded that it was caused by a *Babesia*. They believed this *Babesia* to be parasitic in a squirrel (*Spermophilis columbianus*), and to be spread to human beings by a tick, *Dermacentor reticulatus* (= *D. occidentalis*). In 1903 Anderson was instructed to investigate the disease, and as a result of his inquiries he supported Wilson and Chowning as regards both the parasite and the tick. In 1905 Styles published his zoological investigation into the cause, transmission, and source of Rocky Mountain spotted fever, in which he failed to find evidence of the existence of the parasite in man or squirrel, and of the transmission by the tick. His researches were supported in the same year by Ashburn. In 1906 King found distinct experimental evidence of the transmission of the disease by the tick. From 1906 to the present time Ricketts has been working at the etiology of the malady, and has proved that the tick *D. occidentalis* spreads the disease—a conclusion which he has supported by experiments on guinea-pigs and monkeys; but he says that the credit for proving the transmission of the disease from man to man by the tick must be given to McCalla and Brereton. In 1908 Ashburn and Craig published an excellent paper on this and the tsutsugamushi disease, which they indicate to be distinct from one another, and in this paper Ashburn accepts the transmission by the tick.

Climatology.—The disease is only known in the United States in Montana, Idaho, Nevada, Wyoming, and Oregon. In Montana it is found in the Bitter Root Valley, on the eastern slopes of the Bitter Root Mountains, and from there to the western bank of the Bitter Root River, by which it is apparently bounded, the worst area being from Lo-lo to Como, a distance of about fifty miles in length, but only about four to five miles in breadth. This country has a considerable snowfall, which, though it begins to melt in March, lies on the mountains until mid-June. The melted snow drains into the river, which does not reach low-water until July. It is only during this period that the ticks (*D. occidentalis*) appear in large numbers, and infest men and animals who pass through the forests, thickets, and uncultivated regions. The disease is also known at Rock Creek, twenty miles, and at Bridger, 200 miles east of the Bitter Root River. In Idaho it occurs throughout the entire valley of the Snake River, including its tributaries, and the foot-hills in the neighbourhood. In Wyoming it is found at Cody and Meeteetse. In Nevada it is only known in the north, in the valley of the Quinn River, where it was recognized as far back as 1887. In Oregon it is said to be mild, and to be found only in the eastern portion, towards Idaho.

It will be noted that these districts extend from 40° to 47° N. latitude, and that the elevation is about 3,000 to 4,000 feet above sea-level.

Wilson and Chowning noted that the cases occur from March to July, as is shown by the following list, taken from their report :

March	6 cases.
April	24 ,,
May	46 ,,
June	35 ,,
July	5 ,,
Spring (exact month not known)	10 ,,
Total	126 ,,

This seasonal occurrence is associated, as stated above, with the prevalence of *D. occidentalis* during the same months.

Ætiology.—According to Wilson, Chowning, and Anderson, the cause of the disease is a *Babesia*, but Stiles, Ashburn, and Ricketts have failed to find this parasite. The bacterial growths so far obtained from cultures of internal organs or of the blood can be considered as merely accidental contaminations. On the other hand, Ricketts has shown that blood taken from a human being suffering from the disease can be inoculated successfully into guinea-pigs and monkeys (*Macacus rhesus*), and that the transmission from animal to animal can go on apparently indefinitely (100 generations). These inoculations produce a disease characterized by an incubation, a fever, an eruption, and post-mortem appearances similar to those found in human cases. No bacteria can be cultivated from the internal organs or blood of the infected animals, nor can any parasite be seen, but the virus exists not merely in the serum, but so closely attached to the corpuscles (white and red) that it cannot be separated from them by washing ; moreover, it will not pass through the pores of a Berkefeld filter. Immunity follows an attack, and hyperimmunity can be induced in guinea-pigs. At the time of writing Ricketts is attempting to prepare a vaccine and a serum.

The virus can be acquired and transmitted by the larva, the nymph, and the male or female adults of *D. occidentalis*, and in a few instances can pass through the eggs into a second generation of ticks.

Infected ticks are found but sparingly in Nature. Thus, of 513 ticks found on animals, 296 or more were allowed to attack guinea-pigs, with the result that only one of the animals took the disease after an incubation of seven days. The infected guinea-pig was found to have thirty-six male ticks upon it, all of which had come from a horse.

A tick fed on a human being suffering from the disease communicated it first to a man and afterwards to a woman by its bites. Ricketts, examining the blood of patients and the eggs of infected ticks, has observed peculiar bacillary-like structures, which show bi-polar staining. He has not succeeded in cultivating the germ.

With regard to predisposing causes, there are sex and age influences to be noted. Men are more frequently attacked than women, and the most common age is from fifteen to fifty years, both of which merely signify that persons performing outdoor work run a greater risk of infection than those otherwise employed.

Pathology.—As the causation of the disease is unknown, remarks with reference to the pathology must necessarily be limited to the morbid anatomy. Rigor mortis is well marked, and the skin shows lividity in dependent and petechiæ in non-dependent parts, and at times the marks of the tick-bites may still be visible.

The pleura, lungs, and pericardium, and most of the organs, are normal, but petechiæ may be seen on the epicardium ; while the liver and spleen are enlarged, congested, and soft, and the kidneys are congested, and may show subcapsular hæmorrhages. The microscope shows capillary congestion of the organs, with an excess of leucocytes, and an extravasation into and pigmentation of the skin. Acute parenchymatous degenerations of the heart muscle, the spleen, liver, and kidneys, are also to be noted.

Symptomatology.—The incubation period varies from two to eight days, during which prodromata, in the form of irritation in the tick-bites, from which pains may radiate, and chilliness with malaise and nausea, may be experienced.

The illness often begins with a distinct chill, accompanied by severe headache, pains in the back and other parts of the body, and a rapid rise of temperature to 103° F. to 104° F., associated with a furred tongue, a dry skin, yellow and congested conjunctivæ, an irritating cough, epistaxis, and the passage of febrile urine.

The fever continues to rise, with slight morning remissions, until a maximum of 105° F. to 107° F. is reached about the fifth to the twelfth day. About the third day (second to seventh) a macular eruption appears on the wrists and ankles, which quickly spreads up the arms and legs on to the back, forehead, chest, and abdomen, so that the whole body is included in about one to two days. The macules vary in size from 1 to 5 millimetres in diameter. They are not elevated, and at first disappear on pressure, but later become permanent, and finally turn petechial about the sixth to the tenth day. Associated with the eruption is a dusky-red mottling of the skin, and often a subicteric tinge of both the skin and the conjunctivæ. The eruption is, however, by no means always well marked, and, in fact, mild cases have been reported in which it was absent.

The pulse is from the first very rapid, reaching from 110 to 150 per minute, and not as a rule in proportion to the temperature. At first full and strong, it becomes gradually feebler and smaller, and is often dicrotic, and in severe cases may be intermittent and irregular. The blood shows a diminution of the erythrocytes and hæmoglobin, with a slight increase in the total number of leucocytes and a relative increase of the mononuclear leucocytes ; but in considering these blood-counts, allowance must be made for the altitude at which the disease occurs. Œdema of the face and limbs may be present in severe cases.

At first the tongue is covered by a thick white fur, but later it becomes dry, cracked, and brownish, and sordes collect on the teeth. Nausea may be present during the first week, but is more common in the second, and generally lasts till the end of the illness. Constipation is usually present throughout the attack, and the liver is often slightly enlarged, while the spleen extends beyond the costal margin, and is tender. There is usually a slight sore throat, and there may be signs of a mild bronchitis, associated with an increase in the number of respirations, which may reach from twenty-six to sixty per minute.

The urine presents the usual febrile character, and often contains a trace of albumin, which occasionally may reach considerable proportions, and be accompanied by a few granular casts. The mind is usually clear, but in severe cases a low muttering delirium may occur.

After the fever has reached its height on the fifth to the twelfth day, the temperature either declines by lysis, and recovery takes place, or it remains high, and, a typhoid state developing, death ensues. If the former event is to take place, the temperature, falling by lysis, reaches normal about the fourteenth to the eighteenth day, the eruption commences to fade, and desquamation begins, which extends all over the body, while the other symptoms gradually abate and the patient becomes convalescent. If, however, death is to ensue, the temperature remains about 104° F. to 106 F°., but sometimes shows a sudden final fall just before the fatal event.

Convalescence may take some time, and it is said that the sites of the eruption are clearly visible even twenty-four days after recovery if a warm bath is taken.

Complications.—Pneumonia is a comparatively frequent complication, but gangrene of the fingers, toes, and skin of the scrotum and penis may occur.

Diagnosis.—The malady may be difficult to differentiate from typhoid fever, typhus, and the Japanese river fever. From typhoid fever it can be distinguished by the more acute onset, the petechial eruption, commencing on the hands and wrists, the absence of marked intestinal symptoms, and the presence of leucocytosis. In doubtful cases all the modern bacteriological methods—serum reaction, search for the *Bacillus typhosus* in the blood, stools, and urine—will have to be used to exclude typhoid.

The distinction between spotted fever and typhus on clinical grounds seems to us impossible. Though in typhus the disease may end more often by crisis than by lysis, all the other clinical symptoms, and the appearance of the eruption, are practically identical; in fact, Sambon and others believe that the Rocky Mountain spotted fever and typhus are the same entity. Possibly typhus and Rocky Mountain spotted fever are due to two varieties of the same organism, or two very closely allied species, in the same way as African, European, American, and Indian relapsing fevers are due to very closely allied organisms.

The Japanese river fever may present a course very similar to the Rocky Mountain spotted fever, but the presence of one or more eschars near the genitals or the axilla, and the eruption beginning on the face, and not becoming petechial, are characteristic.

Prognosis.—It appears that the prognosis is much more serious in some localities than in others. In Montana the mortality has been as high as 90 per cent., while in Idaho it has always been very low (2½ per cent.). The reason for this difference is not apparent. When the eruption is not much marked and not generalized, the prognosis is favourable.

Treatment.—Quinine has been advised and given in large doses, but it does not show any specific effect. The treatment can be only symptomatic. To relieve the severe headache cold applications may be used, or, with prudence, small doses of antipyrin, or pyramidon, or Dover's powders. Large quantities of water should be drunk, so as to flush out the kidneys. The water may be slightly acidulated. Tepid sponging is useful and refreshing. When the temperature rises above 103° F., cold sponging should be used, and, if necessary, the cold bath or cold pack. Should the pulse become small and irregular, cardiac stimulants must be administered. The room should be darkened, and the patient kept undisturbed.

The diet should be liquid, chiefly milk and broths. Alcoholic stimulants may be indicated in some cases.

Prophylaxis.—This consists in avoiding as much as possible localities where the ticks are abundant, and destroying these arachnids. A tick should be removed by applying ammonia, turpentine, kerosene, or carbolized vaseline, and then the bite may be cauterized with pure carbolic acid. Some authorities advise the internal administration of quinine, but this does not prevent the development of the fever.

TSUTSUGAMUSHI DISEASE.

Synonyms.—Japanese River fever, Flood fever, Island disease (Shima disease), Kedani disease ('kedani' is the hair-louse), Aka Mushi* disease ('aka mushi' means 'red insect'), Shima Mushi disease (Island Bug disease), Tochu-bio, Shashitsu.

Definition.—Tsutsugamushi disease is an acute endemic febrile disorder caused by the bite of a mite, producing a small local necrotic area, painful enlargement of the proximal lymphatic glands, and an exanthematous eruption.

History.—Tsutsugamushi disease is said by Ashburn and Craig to have been mentioned under the term 'shashitsu' in Chinese writings more than one thousand years ago, when it was described as a fever due to the bite of a mite, which produced a pustule in summer-time in people who entered those parts of the country which had been flooded by the spring rains. The Japanese literature on the subject is considerable, but the descriptions written in European languages are not extensive, the earliest contributions being by Palm in 1878 and Baelz in 1879, while Ashburn and Craig, in 1908, give an excellent account of the disease and its causation, together with a comparison with the spotted fever of the Rocky Mountains.

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* 'Mushi' is the Japanese for a bug or insect.

Climatology.—The geographical distribution is limited to the island Nippon, of Japan, where it is confined to the districts Akita-ken and Nugata-ken (' ken ' means a ' district '), in which certain lands are flooded in June, in the former district by the Rivers Omonogawa and Minasegawa, and in the latter by the Rivers Shinanogawa, Akagawa, Uwonumagawa, and Hajadegawa. It is, further, limited to certain parts of the regions flooded by these rivers. The floods only last a few days, and the regions do not become dangerous till after a few weeks, when a red mite appears, which may attack any person entering these places. In fact, so great is this danger that the lands have been abandoned, except by the very poor, who enter them in order to cultivate hemp or corn, or to gather mulberry-leaves to feed silkworms. The disease is to a limited extent transportable with corn, hemp, and other articles. It occurs most frequently from the middle of July to October.

Ætiology.—The causation of the disease is not known, but there are three theories which have been supported by various investigators.

These theories are :

1. *The Bacterial Theory.*—Many bacteria have been described as the cause of the disease, the first being a *Proteus*, found by Bälz and Takana, associated with staphylococci and streptococci in the lungs, sputum, and urinary sediment.
2. *The Protozoan Theory.*—Ogata considers that the cause of the disease is a *Plasmodium*, which he states he has found in the blood of numerous patients. Ogata's observations have not been confirmed.
3. *The Chemical Theory.*—Tanaka believes that the true cause is a toxin contained in the body of the mite, and introduced by its bite.

The only certain facts which we know concerning the ætiology of this disease is that the symptoms follow the bite of the larva of an unknown species of *Trombidium*, and that immunity is not conferred by an attack. This larva (akamushi), which, though bright red or orange in colour, is so small that it is almost invisible to the naked eye, is found in large numbers on the inner surfaces of the ears of field-mice (*Arvicola natanedzumi* Sasaki) caught in July and August in the infected regions. The akamushi of other regions do not cause the disease, which, of course, is against the chemical theory as to the ætiology. Miyajima claims to have infected monkeys by inoculating blood derived from a person suffering from the disease, and also by the bites of the mites. Mice and guinea-pigs are said to be immune—a statement which, however, is opposed by Ogata.

Only poor people enter the infected lands during the months of July to October, and as any person who does so is liable to infection, the disease is mostly found among the poor.

Pathology.—The post-mortem reveals a small ulcer, sometimes still covered by an eschar at the site of the bite, and enlargement of the proximal lymphatic glands. The spleen is enlarged and softened, the lungs are œdematous and congested, and the bronchial mucosa is often slightly swollen and reddened, and the kidneys are inflamed. We are not acquainted with any description of the histology of the organs.

Symptomatology.—The incubation period varies from five to ten days, during which there may be a feeling of prostration, giddiness, and general malaise, but definite prodromata are wanting.

The disease begins with a chill and rigors, accompanied by severe pain in the forehead and temples, and a sensation of weakness, while the temperature quickly rises to 101° F. to 103° F. The patient usually complains of pain in certain enlarged lymphatic glands, which, on inspection, are found to be tender, quite distinct from one another, and freely movable under the skin. A search in the region drained by these glands may reveal a circular vesicle, measuring 2 to 4 millimetres in diameter, but more usually one or more black or brownish necrotic areas of skin, surrounded by a dullish-red areola, are found. These areas indicate the sites of the bites of the mite.

The temperature continues to rise during the next few days, reaching a maximum in the second week, when it may be as high as 105° F. During this time the eschar has been thrown off the necrotic area, and reveals a circular punched-out ulcer, the periphery of which is red and infiltrated, but not painful nor tender. About the fifth to the seventh day an eruption appears on the face in the form of large red papules, which may become confluent on the cheeks, giving the face a swollen appearance. From this situation the eruption spreads all over the body, but more in the form of macules than papules. These maculæ, which are 2 to 5 millimetres in diameter, fade on pressure, but quickly return when the pressure is removed, and do not itch. Between the spots on the trunk and forearms follicular papules may be noted, but the eruption is not so well marked on the arms and thighs.

At first the pulse is full, and not very rapid, varying from 80 to 100 per minute; later it may become small and quick, and at times dicrotic. The first cardiac sound is often impure, and the transverse diameter of the cardiac dulness may be increased.

In the blood the red cells are found to be diminished, and the hæmoglobin proportionately reduced. In mild cases there is often an increase in the large mononuclear leucocytes and lymphocytes, but in severe cases the total number of leucocytes is often diminished, though there may be a relative polymorphonuclear increase.

The tongue is at first moist and slightly coated, but later it becomes dry, brown in the centre, and glazed at the tip and edges. The gums in some cases are spongy, and bleed, while sordes may collect on the teeth, and a few punctiform spots be noted on the palate. The epigastrium and left hypochondrium are tender; the liver, however, is not as a rule palpable, though the spleen is usually slightly enlarged.

The nose and throat are normal, but the rate of the respirations is increased, and the breath-sounds are harsh and accompanied by rhonchi, which can be heard all over the chest. Usually there is a certain amount of coughing, but the expectoration is scanty.

The urine is diminished in quantity, high-coloured, and may contain albumin, and often gives the diazo-reaction. Strangury may occur.

The conjunctivæ are early injected, a feature which becomes more marked as the disease progresses, and is associated with lachrymation.

From the very first there is a great hyperæsthesia all over the body, and there may be delirium at night, and difficulty in hearing.

About the fourteenth day of the illness the eruption begins to fade and the fever to remit, and in the next five or six days the temperature falls by lysis to normal, and, the general condition rapidly improving, convalescence begins. Recovery is usually quick, and by the twenty-first day from the commencement of the attack the patient is well.

In bad cases, however, coma and hyperpyrexia may develop in the second week, and cause the death of the patient. In other cases death may be caused by complications, which may arise either in the second week or during convalescence.

Varieties.—Severe types of the disease end in death about the ninth to the fifteenth day from hyperpyrexia, cardiac failure, pulmonary œdema, or from complications. Mild types, showing only the bite and the enlargement of the lymphatic glands, and associated with but little fever or eruption, quickly end in recovery.

Complications.—The commonest complications are parotitis, melæna, mania, and cardiac failure with pulmonary œdema.

Diagnosis.—The differential diagnosis from Rocky Mountain spotted fever and typhus has already been discussed (p. 716). At the onset—when the inguinal or other lymphatic glands are enlarged and painful—plague might be suspected. The presence of the necrotic area, and, in any doubtful case, the microscopical examination of the gland juice, will enable a diagnosis to be made.

Prognosis.—The prognosis is good in the young, and in second and third attacks, which are always milder than the first. It, however, gets worse as age progresses, and especially in first attacks. The mortality is about 30 per cent., but increases markedly with age, being only 12·5 per cent. in the first, and 57 per cent. in the seventh, decade of life.

Treatment.—Quinine is generally administered, but it does not influence the fever to any marked extent. Narcotics may be required to combat the sleeplessness, and constipation must be relieved by purgatives and enemata. Phenacetin, antipyrin, and salicylates are generally badly borne by the patient.

Prophylaxis.—The prophylaxis consists in the avoidance of the infective regions during the months of July to October inclusive, while the cultivation of the infected regions, and especially the planting of *Eucalyptus globulus* and *Paulonnia imperialis*, are advised, as well as the smearing of the exposed parts of the body with eucalyptus oil and balsam of Peru, which are said to keep away the mites.

The natives believe that the manuring of the infected lands with human fæces for three consecutive years will make them free from the mites, provided there is no flooding during that period.

THE TICK FEVER OF MIANA.

Definition.—A specific fever of unknown cause, brought about by the bite of a tick (*Argas persicus* Oken 1818).

Historical.—Dupré, in 1809, first described this disease, stating that the bite of *A. persicus*, locally known as 'Guerib-guez,' 'Garib-guez,' 'Miané-bug,' or 'punaise de Miana' (Mallèt de Mianèh), was at times dangerous, producing prolonged illness. Kotzebue, in 1819, stated that the natives were immune, and only foreigners suffered. Fischer de Waldheim, in 1823, said that the bite was fatal, and Heller, in 1858, described the effects as being caused by the mechanical injury of the bite of the tick. Taschenburg, in 1873, considered the symptoms to point to a disease, and not merely to the effects of the bite of the tick; and Schlimmer, in 1874, considered the immunity of the natives to be due to the fact that they had been bitten, and so become vaccinated. Mégnin, in 1882, showed that the bite *per se* was not dangerous, and later was supported by Fumouze and Loundsbury.

Ætiology.—The causation of the disease is quite unknown, but some virus must be inoculated when the tick bites, for the disease is apparently confined to Persia; and the experiments of Mégnin, Loundsbury, and others show that in certain regions the effects of the bite are insignificant.

Manson thinks that this virus will some day be found to be a spirochæte, which, indeed, is not unlikely, as *A. persicus* is well known to be the carrier of *Spirochæta marchouxi* Nuttall 1904, which causes a very fatal disease in fowls. Native Persians probably develop a relative immunity due to previous slight infections, but newcomers suffer severely.

Symptomatology.—The knowledge of the symptoms of the disease is very meagre. Severe pain is felt at the site of the bite of the tick, and this is followed by remittent fever lasting from a few days to several weeks, delirium, convulsions, and even at times by death.

Treatment.—The treatment is entirely symptomatic.

Prophylaxis.—According to Nuttall, the Persians burn their villages when they suffer severely from the attentions of the tick. In order, however, to devise a rational method of prophylaxis, it must be remembered that *A. persicus* is essentially a parasite of the domestic fowl and other birds, and that its eggs are laid in batches of 20 to 100 in cracks in the walls, and take three weeks to develop into the larva, which, after sucking blood, in eight days becomes the nymph. This may require several weeks before it becomes the adult, which is said to feed only once a month. After considering this life-history, it will be obvious that fowls should be disinfected with a kerosene emulsion, creozozone, or oil of sassafras in the case of old birds, while young birds may be isolated in cages until the ticks drop off. Houses and fowl-houses should be cleansed and treated by lime and corrosive sublimate, and old nests and roosts should be burnt, and after that the new fowl-houses may be sprayed with kerosene emulsion.

THE INTERMITTENT TICK FEVER OF WYOMING.

Definition.—An intermittent fever due to the bite of *Dermacentor occidentalis.*

History and Geography.—This fever was described by Kieffer in 1907 as being found at Fort D.A. Russell, in Wyoming, United States of America, but his account so far has not been confirmed.

Ætiology.—The fever comes on after the bite of *D. occidentalis*—*i.e.*, the same tick which causes the spotted fever of the Rocky Mountains—but no specific organism has so far been described.

Symptomatology.—The incubation period varies from three to seven days, after which the disease begins suddenly with a rigor, nausea, vomiting, and pains in the joints and muscles. The temperature rises to 103° F. to 104° F., and continues high for twenty-four to forty-eight hours, after which a remission of forty-eight hours occurs, and then another attack, and so on for three to seven attacks. Less frequently the attack resembles typhoid, with a ladder-like rising temperature and abdominal symptoms, but Widal's reaction is absent. There is marked decrease of the erythrocytes and hæmoglobin, and a slight lymphocytosis, due to increase in the number of the large mononuclear leucocytes.

Treatment.—Hypodermic injections of arsenic in some form are recommended as the best treatment for the disease.

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CHAPTER XXVII

THE KALA-AZARS

Indian kala-azar—Infantile kala-azar.

INDIAN KALA-AZAR.

Synonyms.—Tropical Febrile Splenomegaly, Kala Dukh, Dum-Dum fever, Non-malarial Remittent fever, and Cachectic fever.

Definition.—A subacute or chronic specific febrile disease caused by *Leishmania donovani*, and possibly spread by means of some *Cimicidæ.*

History.—In 1869, when the district of the Garo hills was first occupied by the British, a disease believed to be a very severe form of malarial cachexia was found to be endemic. This disease the Garos called 'kala-azar,' which means the black fever, so named from the appearance of the victims. In 1875 it began to spread, and became epidemic, and by its high death-rate attracted attention. In 1882 the first account of the disease was published by Clarke from notes of 120 cases compiled by McNaught, the civil Medical Officer of the district. In 1889, when it had spread into Assam, following the lines of human intercommunication, Giles investigated the epidemic, and concluded that it was agchylostomiasis. In 1894 Stephens, in his yearly report, stated that the disease, though allied to, was distinct from malaria. In 1897 Rogers reported that it was malarial, and this was further supported by Ross in 1899. In 1902 Bentley ascribed the disease to *Micrococcus melitensis*, on the basis of serum reactions.

Up to this point the history of the disease remarkably resembles the present history of blackwater fever. A change now comes over the ætiology, for, in 1900, Colonel Leishman found the parasites already described under the heading *Leishmania donovani* in films taken post-mortem from the spleen of a soldier who died in Netley from fever contracted at Dum-Dum, but he did not publish this discovery till 1903. In July, 1903, Donovan observed the same parasite in blood obtained by splenic puncture performed during life. In 1904 Christophers published a valuable report on the parasite and the disease, and in the same year Rogers observed the development of the parasite into a flagellate organism when splenic blood was incubated at 22° C. in citrate of soda solution.

In 1907 Patton showed that the parasite could be found in numbers lying in the leucocytes in the peripheral blood, and, further, that it became flagellated in the alimentary canal of bugs. In 1905 Pianese found similar parasites in cases of splenomegaly in children in the South of Italy, and afterwards Nicolle made the same observation in Tunis (see p. 730).

In addition to the above-named investigators, much work has been done by Sir Patrick Manson, Low, Statham, and others.

Climatology.—Kala-azar is endemic in parts of India, especially in Assam, Madras, and Calcutta, but can at times become epidemic. It is also found in Arabia, Ceylon, Burmah, Indo-China, and China. In North Africa it is known in the Sudan and Egypt, while a similar condition has been reported in Tunis and Algeria, in Sicily, in Crete, and other islands of the Mediterranean. Probably it is much more widespread than is at present known.

Ætiology.—The parasite *Leishmania donovani* is the cause of the disease, and it is possibly introduced into the human body by the bite of some species of the Cimicidæ. Donovan is inclined to inculpate a *Conorhinus*.

The predisposing causes appear to depend upon, and be capable of explanation by, the habits of bugs, as shown by Patton. Thus the disease, when epidemic, always spreads relatively slowly along channels of human intercommunication, and apparently is directly due to the introduction of an infected human being into the district. It runs in families, in which children particularly suffer, while the class of people who are mainly affected are the poorer sections of the European and native communities. Season and sex appear to have no influence, but there is no doubt about the infection of the dwelling, nor of the capability of the disease of spreading from one dwelling to another.

Pathology.—Introduced into the body, the parasite appears to enter the endothelial cells of a capillary bloodvessel or lymphatic, and to grow therein, and to increase in numbers by simple fission until a very large number—Leishman says upwards of 220—may be counted in one cell. The organs principally affected in this manner are the liver, spleen, bone-marrow, and lymphatic glands, and, to a less extent, the pancreas, kidneys, suprarenals, testicles, and lungs.

The parasites may now escape from the enclosing cell by rupture, and are then taken up by the leucocytes, particularly by the polymorphonuclears, but also by the mononuclears and rarely by the eosinophiles, by means of which they appear in the peripheral blood even in early cases, but are much more common late in the disease, especially if there is diarrhœa due to ulceration of the intestine, in which condition the polymorphonuclear leucocytes are increased in numbers in the peripheral blood, and many of them contain parasites. The further development takes place in the bug, and has been already described, but the full life cycle has still to be worked out.

By some means or other the parasite irritates the organ it infects, causing marked changes in the spleen, liver, and bone-marrow, and also causing ulceration of the intestine and skin.

The Blood.—The examination of the blood is most important, because, firstly, the parasite may be found in a leucocyte if carefully looked for, even in the early stages of the disease; secondly, the leucocytic changes are of the utmost importance. There is marked anæmia—54·2 per cent. of Rogers' cases giving from 4,000,000 to 2,500,000 corpuscles per cubic millimetre—and the hæmoglobin is reduced in proportion to the erythrocytes, the colour-index being normal. There is a most marked leucopenia, and Rogers reports that in 42·1 per cent. of his cases the leucocytes were 1,000 or less, in 30·3 per cent. 1,000 to 2,000, and in 22·6 per cent. 2,000 to 3,000. The proportion of white to red, according to the same author, is less than 1 : 1,500 in 67·9 per cent., or, if inflammatory cases are excluded, in nearly 90 per cent. of the cases he examined. There is a reduction in the polymorphonuclear leucocytes and in the eosinophiles, and an increase in the mononuclear leucocytes and lymphocytes. The diminution of the polymorphonuclear leucocytes is thought to explain the tendency to bacterial infections. The coagulability of the blood is decreased, which explains the tendency to hæmorrhage, and renders splenic puncture very dangerous.

The Urine.—The urine in our cases did not show anything abnormal.

Morbid Anatomy.—The body is much emaciated, and there is marked muscular atrophy, together with œdema, enlargement of the spleen, and often of the liver, ulceration of the skin and intestine, sometimes hæmorrhage in various places, and generally the presence of some complication. The spleen is greatly enlarged, firm, and deep red in colour, though it may at times show malarial pigment. The capsule and septa are thickened, and the whole organ is congested with blood, and contains numerous mononuclear cells and macrophages full of parasites.

In the liver, which may or may not be enlarged, the most marked changes are in the intralobular capillaries, which are dilated and contain macrophages, derived from their endothelial wall, full of parasites, while the liver cells are atrophied and degenerated. Cirrhosis has been noted in some cases.

The bone-marrow contains numerous parasites in the usual cells, and, as in malaria, the yellow marrow is converted into red, and is soft and diffluent. The skin may show papules and ulcers, in which the parasites can be found, while the colon is often ulcerated, or shows the cicatrices of old ulcers.

Symptomatology.—The incubation period appears to be very variable, and, indeed, it is difficult, in a chronic disease of this nature, to decide when it first begins. It is said to range from three weeks to several months.

The onset may be heralded by a rigor, which may be repeated daily, and by an attack of irregular, high, remittent fever, which may early show two remissions per diem in a four-hourly temperature chart. This double remission is considered by Rogers to be almost diagnostic of the disease. Towards the end of the third to sixth week of the fever the temperature declines, and the initial stage of the disease may be said to have terminated. During this period, however, the spleen and liver will have enlarged, and may be both painful and tender. Headache is present at times, but is not severe. Nausea and vomiting are unusual, while the bowels are regular, and there is no abdominal distension. The pulse may be slow or quick.

The attack, however, may begin with a continuous fever, which shows two fluctuations in the twenty-four hours, which Rogers considers as almost diagnostic of the disease. In other cases the disease may begin with gastro-intestinal disturbances or with dysenteric symptoms, or quietly, without any marked initial stage, the patient gradually developing an enlarged liver and spleen, anæmia and weakness.

The course of the disease, after the decline of the temperature, is marked by what is called an apyrexial interval ; but it appears that—in some cases, at all events—there is a slight daily rise of temperature, not exceeding 100° F. After some weeks this apyrexial interval ends in an attack of fever resembling the onset. Periods of apyrexia and pyrexia now alternate with one another, while the spleen, and sometimes the liver, enlarge. Anæmia commences and increases, while asthenia not merely appears, but deepens, until the wretched patient presents the typical appearance, which may be described as follows : He is thin and wasted, with the abdomen much swollen and protuberant, the chest so thin that the ribs show clearly, the arms and legs wasted, the cheeks sunken, the nose sharp, and the ankles puffy, while the skin and tongue are often

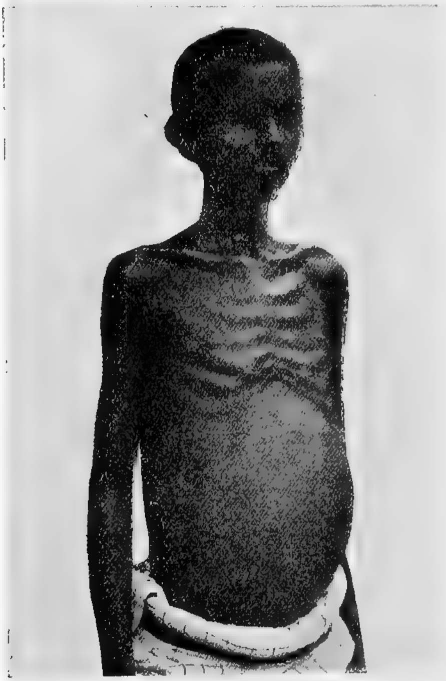

FIG. 296.—INDIAN KALA-AZAR.

The distension of the abdomen by the greatly enlarged spleen should be noted. Photograph of a case in the Tropical Clinic, Colombo.

distinctly darker than they should be, the former being furfuraceous.

On examining the swollen abdomen, the enlarged spleen may be felt reaching almost to the pelvis, while the enlargement of the liver may be marked or may be absent. In this condition intestinal disturbances in the form of diarrhœa or dysenteric attacks are common, and may be due to the actual disease or to complication with true dysentery. Dyspeptic symptoms may also be present.

Hæmorrhages may occur from the nose, the gums, the stomach, the bowels, or under the skin. Papular eruptions are to be seen, especially on the thighs, and ulcers may be present. The weakened, emaciated patient may now die of asthenia, but more usually the long-drawn-out illness is brought to a close by some complication. The total duration varies from about seven months to two years, and generally ends fatally.

Complications.—It appears as though the reduction in the number of the polymorphonuclear leucocytes laid the patient open to invasion by pathogenic bacteria, for septic infections, such as cancrum oris, or lung infections—for example, pneumonia, phthisis, and pleurisy—or abdominal troubles of the nature of diarrhœa, dysentery and cystitis, are not uncommonly met with, and may cause the death of the patient. Sometimes, after a severe attack of septicæmia or some other complication, the disease is found to be cured, but this is rare.

Diagnosis.—The only certain method of diagnosis is to find the parasite, and as Donovan and Patton have reported its frequent occurrence, even in early stages, in the peripheral blood, this should be possible, especially if aided by dilution with normal saline solution, and centrifugalization and examination of the leucocytes. In our experience, the search for the parasite in the leucocytes of the peripheral blood requires an extremely long time, and is often negative. If the parasites cannot be found in the blood, an attempt may be made to find them by the examination of the exudate obtained by exciting artificial pustulation of the skin by some irritant, as suggested by Major Cummins. Failing this, there is puncture of the spleen or of the liver, and withdrawal of blood, which can be examined by the microscope. The diagnostic puncture of the spleen in the tropics is, however, not to be undertaken lightly, because splenic enlargement due to leukæmia is by no means unknown, and puncture of the spleen in this disease, or, indeed, in that of chronic malaria, may lead to most unfortunate results. The blood of the peripheral circulation should therefore be examined to exclude leukæmia.

Certainly, the first thing to do is to examine the peripheral blood and exclude leukæmia. Secondly, the coagulability of the blood should be tested by Wright's method, and if found to be decreased, the puncture should not be performed. Thirdly, if the puncture is to be carried out, the liver should be chosen for exploration, not the spleen, particularly in the later stages, in which hæmorrhages are to be feared. In the early stages there may not be so much risk, but it must be done with the greatest care, aseptically, and the patient must be kept at rest for some time afterwards, the site of puncture being covered with an aseptic pad and a firm bandage. The syringe should be sterile, and *perfectly dry*. Rogers recommends that a dose of 30 grains of calcium chloride in a couple of ounces of water be administered directly after a puncture, in order to promote coagulability of the blood.

In the early stages the diagnosis has to be principally made from acute malaria and typhoid, when the positive signs in favour of kala-azar are: (1) Presence of the characteristic daily double remission of the fever; (2) absence of constitutional symptoms, proportional to the severity of the fever; (3) absence of malarial parasites and Widal's reaction, though, of course, the latter reaction is negative in true typhoid during the first week; (4) marked enlargement of the spleen; (5) great leucopenia, especially in relation to the erythrocytes, which, however, may also be found in typhoid and malaria; (6) increase in mononuclear leucocytes; (7) presence of *Leishmania donovani* in the leucocytes.

In advanced cases the diagnosis has to be made from malarial cachexia and agchylostomiasis by (1) the presence of *Leishmania donovani* in the leucocytes of the peripheral blood, or in the juice from the liver and spleen; (2) by the absence of the typical febrile attacks of subtertian or tertian fever; (3) by the absence during the febrile attack of malarial parasites; (4) by the absence of agchylostomes, or, if they are present, by the continuation of the symptoms after their expulsion. Mixed infections of kala-azar and malaria may occur.

Prognosis.—The prognosis is extremely bad, for the mortality appears to vary from 70 per cent. with vigorous quinine treatment to 98 per cent. without this. It is true that some people recover after having nearly died from a complication, or, more rarely, without this episode, but why they recover is not known.

Leucocytosis and increase of the polymorphonuclears are considered to be good signs, while leucopenia and polymorphonuclear decrease are bad signs. Complications, of course, increase with the gravity of the prognosis.

Treatment.—The aim of the treatment is to kill the parasites, and for this purpose Manson and Low recommended the trial of intramuscular injection of atoxyl every day or every second day in doses of 3 grains. Manson has reported two successful cases.

Rogers recommends large doses of quinine—*i.e.*, 60 to 90 grains per diem, to be given until the temperature falls and becomes of a low, intermittent type, and then 20 grains every morning.

In our experience the best treatment is the administration of quinine in massive doses by intramuscular injections, supplemented by a course of quinine cacodylate injections, or atoxyl injections. One of our patients apparently recovered on a treatment of quinine sulphate (30 grains) and euquinine (30 grains) daily by the mouth, together with a daily intramuscular injection of quinine hydrochloride (15 grains) alternating with one of quinine cacodylate (4 grains). Manson has advised antimonial preparations, and Roger a staphylococcal vaccine.

The further treatment is purely symptomatic; thus parasites such as agchylostomes, ascarides, etc., must be got rid of. The patient should have good hygiene and good food. Hæmorrhagic symptoms should be treated by calcium chloride, and diarrhœa and dysenteric symptoms require the remedies mentioned under Dysentery.

The question whether inoculation with the scrapings of a Delhi boil does any good has not yet been answered.

Prophylaxis.—It would appear as though prophylaxis should be conducted on the lines of bug extermination, already described in the chapter on Diptera. It appears that, in contrast to what is the case with infantile kala-azar, dogs are not carriers of the disease.

INFANTILE KALA-AZAR.

Synonym.—Febrile splenic anæmia (Fede). *Anæmia infantum a Leishmania* (Pianese).

Definition.—Infantile kala-azar is a subacute or chronic specific disease due to *Leishmania infantum* Nicolle, and clinically closely resembling Indian kala-azar.

Historical and Geographical.—Fede several years ago described in Italy a form of splenic anæmia among young children characterized by irregular fever, progressive anæmia, and a fatal ending. He considered it a disease by itself, separating it from the non-febrile type of splenic anæmia. Pianese in 1905 called attention to the similarity of the symptoms of Fede's splenic anæmia with kala-azar, and described parasitic bodies in the spleen of the affected children morphologically identical with *Leishmania donovani*. Later Nicolle suggested for the disease the name of 'infantile kala-azar,' and completed the study of the parasite, which he called *Leishmania infantum*. Gabbi apparently considers the disease to be identical with Indian kala-azar, having found it also among adults.

The malady is met with in Sicily, Southern Italy, and northern regions of Africa. Future investigations will probably show that it is endemic in many other countries.

Ætiology.—The malady is due to *Leishmania infantum* Nicolle. The description of this parasite will be found in Chapter XII. Nicolle has succeeded in reproducing the disease in monkeys, and less typically in dogs. He has also found that dogs may be spontaneously affected with *L. infantum*—in fact, in his opinion, the dog acts as a reservoir of the virus, and its ectoparasites, such as fleas, may possibly serve as the transmitting agent to human beings.

Pathology.—The pathology has been carefully studied by Pianese, who finds that the post-mortem lesions are similar to those observed in Indian kala-azar, the spleen and liver being greatly enlarged. Microscopically, there is great increase of the lymphoid tissue in the spleen and hypertrophy of the islands of Langerhans in the pancreas. In the bone-marrow there is hyperproduction of the myeloid and lymphoid tissues.

Symptomatology. — Clinically the disease can hardly be distinguished from kala-azar, except by the fact that it generally affects very young children between one and six years of age. It usually commences with irregular attacks of fever, which do not subside under quinine administration. A progressive anæmia develops, the blood showing a great decrease in the number of erythrocytes. The leucocytes are decreased in number, the leucocytic formula being mononuclear. Gradually the spleen and liver become greatly enlarged, and the general condition worse, the child showing an emaciated appearance and a bulging abdomen. Transitory œdema of the face, hands, and feet may appear, and in several cases cutaneous hæmorrhages may develop in the last stage. The duration of the malady varies between a few months and several years, and generally terminates fatally. Occasionally apparent recovery may take place, according to Nicolle.

Diagnosis.—Irregular fever, not influenced by quinine, in a very anæmic child with enlargement of the spleen should always arouse the suspicion of infantile kala-azar. A definite diagnosis can only be made by finding *L. infantum* in the splenic or liver juice obtained by puncture, the technique of which has already been given above.

Pianese recommends the puncture of the superior epiphysis of the tibia and the microscopical examination of the marrow, which is richer in parasites than the spleen or liver.

Treatment.—This is most unsatisfactory. The same drugs may be used as in kala-azar, only, of course, in smaller doses. Atoxyl is perhaps the best.

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CHAPTER XXVIII

THE TRYPANOSOMIASES

Synonyms — Definition — History — Geographical distribution and Epidemiology—Ætiology—Pathology—Symptomatology—Diagnosis—Prognosis—Treatment—Prophylaxis—References.

AFRICAN TRYPANOSOMIASIS (SLEEPING SICKNESS).

Synonyms.—Sleeping Dropsy, Negro Lethargy, Morbus Dormitivus, Maladie du Sommeil (French), Afrikanische Schlafkrankheit (German), Trypanosomen Fieber (German), Doença de Sonno (Portuguese), Letargia dei Negri, Malattia del Sonno (Italian). Native names are very numerous—Lalangola, Láá La-negulo, N'tansi, Mongota, Kónje Márree, Tula Manugina, Nelavare, Dadane, Toruahebue, etc.

Definition.—Trypanosomiasis is an acute or chronic specific infection, caused by *Trypanosoma gambiense* Dutton and disseminated by *Glossina palpalis* Robineau-Desvoidy, and characterized by an inflammatory condition of the lymphatic system leading to a meningo-encephalitis and a meningo-myelitis.

History.—No mention of sleeping sickness is to be found by writers in the eighteenth century, and it is not until 1803 that Winterbottom gives the first account of the disease as he met with it on the West Coast of Africa near Sierra Leone. His description is quite understandable, and he draws attention to the presence of the enlarged glands of the neck, the association of which with the disease was so well understood that slave-traders would not buy slaves who had enlarged glands.

In 1808 Moreau de Jonnès drew attention to the disease in negro slaves in the Antilles. In 1849 Clarke on the Gold Coast, Davis and Daniell on the Guinea Coast, and Ferreira at St. Thomas, came across it. During the next twenty years a number of observers described the disease, among whom it is important to note that Guérin met with it in 1869 in Martinique in negro slaves who had been imported from Africa. In 1876 Corre gave a good description of the disease as he knew it in Senegal.

In 1891 the first case was brought to London, and was studied by Sir Stephen Mackenzie; and in 1900 two more cases were brought to London, this time under the care of Sir Patrick Manson. The morbid anatomy of these cases was carefully studied by Dr. Mott, who has done so much to clear up the pathology of this disorder.

In 1901 Forde and Dutton found a trypanosome, *T. gambiense* Dutton 1902, in the blood of a patient suffering from a peculiar type of fever on the Gambia (Gambia fever, Dutton's disease). In 1902-03 Castellani found the same organism in the cerebro-spinal fluid of persons suffering from sleeping sickness, and in 1903 reported that it was the ætiological basis of the disease. Low and Castellani gave a clinical account of the disease which is largely followed in this chapter, and Christy published many interesting epidemiological features concerning the disease. In 1903 Bruce and Nabarro showed that the trypanosome was spread by *Glossina palpalis* Robineau-Desvoidy, a conclusion already reached by Sambon and Brumpt on epidemiological grounds. From 1903-05 much clinical, experimental, and epidemiological work was done by Dutton, Todd, and Christy, the Commissions of the Royal Society and various Governments, and by the members of the Liverpool School of Tropical Medicine. Recently Kleine has experimentally shown that *T. gambiense* undergoes a cycle of development in the *Glossina palpalis.*

Koch, Laveran, Mesnil, Minchin, Blanchard, Greig, Gray, Tullock, Kinghorn, Montgomery, Martin, Lebœuf, and Roubaud, have all recently studied the disease and its epidemiology, and an International Conference was held in 1907 in London, and a Bureau for the study of the disease founded. This Bureau is at present issuing monthly bulletins, which are most valuable to the student of the disease.

The history of the treatment of trypanosomiasis has been reviewed in a paper by Boyce and Breinl, and in the first bulletin of the Bureau, in both of which it is pointed out that arsenic was long ago considered beneficial for the trypanosomiases of animals.

Livingstone first applied the drug to a horse for purposes of treating nagana. Since then it has been used for the same purpose by several persons, notably by Lingard (1893) for surra and by Bruce (1896) for nagana, while Laveran and Mesnil introduced sodium arseniate in 1902 for the same disease, while E. J. Moore and Chichester advocated the use of hypodermic injections of arsenic, and Thomas and Breinl of the same of sodium arseniate. In the meanwhile Manson had treated several cases of sleeping sickness with arsenic (liquor arsenicalis); and Ehrlich and Shiga had treated various experimental trypanosomiases with colouring compounds belonging to the benzo-purpurin group, of which trypharred is the best known. Thomas, in 1905, first brought the drug 'atoxyl' to the notice of the profession as a means of treatment of trypanosome affections. This represents so far the greatest progress in the treatment of the disease.

The beneficial action of atoyxl in sleeping sickness was confirmed by Broden, Van Campenhout, Manson, Koch, and many others. In 1907 Ehrlich and his pupils, Franke and Roehl, discovered the very important fact that trypanosomes may, after a time, become atoxyl-resistant. Ehrlich therefore suggested mixed or alternating treatment with various preparations, and the same suggestion, though based on different grounds, was made by Moore, Nierenstein and Todd.

Geography and Epidemiology.—The disease was first noticed on the West Coast of Africa at Sierra Leone, but was soon found to extend far southwards, and was also noted to be imported from this endemic area at times to the West Indies, where, however, it soon died out, becoming neither epidemic nor endemic. This fact clearly proved that, though the disease may be introduced by man along channels of intercommunication into a strange country, some other factor is necessary before it can spread from the infected new-comer to the inhabitants. This factor we now know to be a tsetse-fly.

In 1882 the disease had a geographical distribution from Senegal to Loando, and also to the islands of the Gulf of Guinea. Gradually, as civilization spread, it became known that the disease was not confined to the coast, but extended far inland. Thus, in 1898 it was known to be at Jebba, on the Upper Niger, and at the Stanley Falls, on the Upper Congo. In the meanwhile Stanley had travelled across Africa with a large number of Congolese followers, and had relieved Emin Pasha and his followers at Wadelai, on the Victoria Nile. These followers of Emin Pasha, together with some of Stanley's expedition, who had settled in the country about Kavali, to the west of the Albert Nyanza, were brought by Sir F. Lugard, for political reasons, to Busoga and Uganda. It appears not improbable that Christy and Hodges are correct when they state that they believe that the disease was carried from the Congo by Stanley's men, and that they and Emin Pasha's people brought the disease with them into Busoga and Uganda when they were moved from Kavali. But, be that as it may, the fact is clear that when, in 1900, the Cooks first noticed the disease in Uganda, it was widespread, and had been there for some time, and it seems probable that Busoga was infected in 1896. Certainly, in 1901, Mengo, the Sese Islands, and the western shores of the Victoria Nyanza, were infected, and the disease spread in 1902 to the eastern shores and to German East Africa.

In 1904-05 Dutton and Todd found that it had become widely disseminated throughout the Congo Free State, spreading by human agency along trade routes, and expressed the opinion that before long it would pass from the Congo into Eastern Rhodesia; and, judging from the 1908 report of Kinghorn and Montgomery this prophecy is coming true, for the disease has already crossed the frontier to the south of Lake Mweru; while these observers consider that it will also be introduced across the frontier between that lake and Tanganyika.* It appears also to be spreading northwards from Uganda, for Greig, in 1904, found it at Wadelai, on the Victoria Nile, but not as high as Nimuli. Captain Ensor, in his report published in 1908, is unable to state definitely whether the Bahr-el-Ghazal Province of the Sudan has or has not become infected, but apparently considers it probable that it has, or will, become so infected.

Therefore the distribution of the disease at the present time may be said to extend along the West Coast of Africa, from St. Louis, in Senegal, to Mossamedes, in Angola; from the coast to Timbucktu, on the Niger; through the whole of the Congo into Uganda and Rhodesia; from Uganda and Busoga southwards to German East Africa; and northwards, perhaps, into the Bahr-el-Ghazal Province. The discovery of the tsetse-fly in Arabia makes it possible that the disease may some day still further extend its area.

There does not appear to be any seasonal influence on the disease.

Ætiology.—The older theories of emotion, sunstroke, beri-beri, malaria, food intoxication, *Filaria perstans*, *Rhabdonema strongyloides*, *Agchylostoma duodenale*, and the various bacterial theories, are now merely of historic interest, as the cause of the disease is known to be *Trypanosoma gambiense* Dutton 1902, for a description of which see Chapter XII.

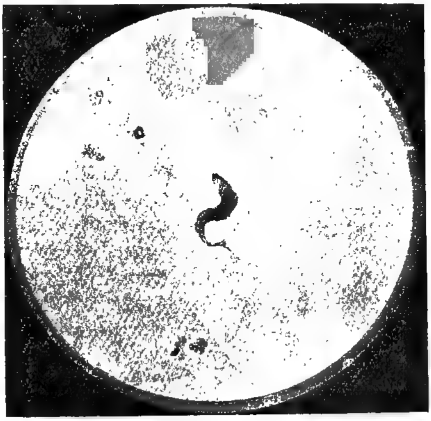

FIG. 297.—TRYPANOSOMA GAMBIENSE DUTTON.

Preparation from the cerebro-spinal fluid of a case of sleeping sickness.

But though this is known, and also that the infection can be spread by the bite of *Glossina palpalis* Robineau-Desvoidy (described in Chapter XX.), it is not certain that other flies may not also help in the dissemination of the disease. Hodges considers that the evidence of the theory that *G. palpalis* is mainly responsible for the disease is growing more certain, and though Koch shows that *G. fusca*, *G. pallidipes*, and *G. morsitans* can become artificially infected, this must be exceptional in nature. Mesnil supports this theory by pointing out that the geographical distribution of the disease and fly agree, still, there are observers who think differently. Thus, the Liverpool Expedition implicate *G. fusca*, *G. morsitans*, *G. pallidipes*, and *G. longipalpis*, while Martin, Lebœuf, and Roubaud suspect mosquitoes belonging to

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* Whether the peculiar disease called 'Gotsello' reported in N'ganiland is sleeping sickness has not yet been decided.

Stegomyia and *Mansonia*, mostly because they noted the infection of young children on the Congo.

Manson, having noted that European females appear specially liable to attack, suggests that possibly some blood-sucking parasite—*i.e.*, a pediculus or bug—may have something to do with the disease. Koch also holds that the disease may be spread by sexual intercourse. In our experience, the trypanosome is disseminated by *Glossina palpalis* Robineau-Desvoidy, and practically by it alone, as shown by Bruce and Nabarro and Kleine. According to some authorities, the tsetse-fly acts simply as a carrier of the trypanosome; according to others, the trypanosome undergoes in it a true developmental cycle. The latter would seem to be the true explanation, as Kleine has proved that infected *G. palpalis* after a period of non-infectivity lasting two to three weeks, becomes again capable of transmitting the disease, and remains infective several months and perhaps longer.

Sambon believes that the trypanosome will be found to infect the larvæ of the flies, and that the infection will be found to be due to the second generation, but at present there is no proof of this. The questions as to where and how the fly feeds is much discussed. Koch thinks that the crocodile is essential to the fly, but Hodges has shown that the *Glossina palpalis* exists where crocodiles are absent.

To summarize, there can be no doubt that the disease is caused by *Trypanosoma gambiense*, and that it is disseminated by *G. palpalis*, but it is not absolutely proved that this fly alone is responsible, and that other tsetse or blood-sucking flies, or even insects, are incapable of spreading the disease, though, in our opinion, the strongest evidence is in favour of *G. palpalis* as being alone the disseminator of the disease.*

Race has not been noted to have any influence, and the predisposing influences of sex (female), as noted by Manson, and of age (young children), as noted by the French observers, require confirmation.

Occupation, however, has a considerable influence, for persons who live near the shores or work along the shores, such as fishermen, are more liable than others, because of the distribution of the fly.

Pathology.—The pathology of the disease has been mainly elucidated by Mott and the Portuguese Commission (Bettencourt, Kopke, Rezeide, and Maude), and appears to be a chronic inflammation of the lymphatic system, probably caused by toxins produced by *T. gambiense*.

The trypanosome either enters the lymph-stream directly after the bite of the fly, and is blocked in the lymphatic glands, which it inflames, and through which it passes to the blood-stream and cerebro-spinal fluid, or, less probably, it enters the blood-stream first, and escapes by rupture of a capillary into a lymph gland. But the polyadenitis is not the only change induced, for the lymphatic tissues of the intestine (solitary or agminated glands) are also inflamed, and the heart and other organs infiltrated with lymphocytes. This stage is marked by fever, but sooner or later, as a result of this lymphatic disease, changes are induced in the membranes and substances of the brain and spinal cord (chronic meningo-encephalitis and meningo-myelitis), especially along the course of the vessels, which result in the proliferation of the neuroglia and in a lymphocytic accumulation around the vessels. These two processes compress the vessels, and lessen the supply of blood to the cells of the brain and spinal cord, in which, as the result of malnutrition, changes ensue, which produce the typical symptoms of the cerebral stage of the disease, which is often called sleeping sickness.*

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* Kleine has occasionally observed a partial development of the trypanosome in *Glossina morsitans*, but these flies never become infective.

Towards the end secondary infections with bacteria may take place, the most constant of these being due to streptococci and the pneumococcus, which probably shorten the life of the patient.

Cerebro-spinal Fluid.—The cerebro-spinal fluid was first studied by Castellani, and it may be noted here that it was during his researches on the leucocytic formula that he discovered *Trypanosoma gambiense* for the first time in sleeping sickness. More recent researches are those by Broden and Rodhain. During the first stage of the disease it is usually of normal appearance, and clear, while on centrifugalization there is practically no sediment, though occasionally a few small mononuclear cells may be present, and trypanosomes are, as a rule, absent.

In the sleeping-sickness stage it is often slightly turbid, and contains an amount of serum albumin and serum globulin ; and on centrifugalization some sediment is obtained, consisting of a few cells, which are mostly mononuclear leucocytes, endothelial-like and vacuolated cells, while trypanosomes, adult and so-called amœboid forms, are almost constantly present.

Morbid Anatomy.—The macroscopical changes found post-mortem are principally in the central nervous system and in the lymphatic glands, but pathological changes brought about by complications may also be noted.

The body is usually emaciated and anæmic, rigor mortis is well marked, and the skin may be normal, or dry and desquamating, or may show pustular eruptions on the hands and forearms, or ulcers on the feet which are generally due to jiggers (*Dermatophilus penetrans*). Enlargement of the lymphatic glands of the neck and groins is generally easily seen. On opening the brain-case, it will be noted that the under surface of the scalp is pale, that the dura mater may or may not be adherent to the bone, that the cerebro-spinal fluid is increased in quantity, and the gyri of the brain are often flattened. On careful examination, the pia-arachnoid will be found to be thickened in places, and may or may not be adherent to the grey matter. The brain substance, which is generally firmer than normal, but may be soft and œdematous, is usually congested, and the fluid in the ventricles is increased.

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* The trypanosome apparently cannot pass through the placenta, as infected women give birth to healthy babies.

With regard to the spinal cord, it will be seen that there is an increase of fluid, which, if examined with the microscope after centrifugalization, generally shows leucocytes and trypanosomes. The cauda equina may be found at times surrounded by gelatinous tissue. The cord itself is often congested, and hæmorrhages have been described.

The lymphatic glands of the submaxillary region, anterior and posterior triangles, around the bronchi, of the mesentery, behind the peritoneum, as well as those of the inguinal and femoral regions, may one or all be enlarged, congested, and even hæmorrhagic. At times abscesses are found in these glands, but they are due to secondary infection. The abdominal cavity often contains some straw-coloured fluid, and the pericardial fluid may also be excessive. There may be some increase in size of the lymph-follicles and Peyer's patches of the small intestine. The lungs may show signs of pneumonia and other complications. The other organs are usually not markedly affected.

The microscopical examination of the organs has been performed with the greatest care by Mott and Breinl and the members of the Portuguese Commission.

The utmost care must be taken to distinguish between the lesions due to *T. gambiense* and those caused by terminal infections such as the diplococci and colon bacilli; for these infections may give rise to chromatolysis in the nerve cells and degeneration in the nerve fibres of the brain (pons and medulla) and spinal cord (especially in the posterior and lateral columns), and perhaps in the peripheral nerves, which have nothing to do with the disease in question. With this proviso the microscopical examination is characterized by a round-celled infiltration surrounding the vessels of the pia-arachnoid of the brain and spinal cord. This infiltration, first described by Mott, is best seen in the membranes, where there is an accumulation of cerebro-spinal fluid, and in the brain, around the vessels of the medulla, pons, cerebellum, and those entering the base. The process appears to begin with a growth in size, and then a proliferation of the neuroglia elements, which has been minutely described by Eisath, and is found, not merely around vessels which show a small-celled infiltration, but around those which do not. Round cells are found later in the meshes of this proliferated glia.

These cells are (*a*) lymphocytes; (*b*) peculiar cells called the 'plasma cells of Marscholko,' characterized by the nucleus becoming situated at one end of the cell, and staining blue with methylene blue and eosine, while a clear halo separates it from the cytoplasm, which stains pink; (*c*) 'morula cells of Mott,' which are large round or oval cells with an eccentric blue nucleus and a cytoplasm containing a clear eosinophile area; (*d*) a few mononuclear leucocytes; (*e*) a few polymorphonuclear leucocytes. The cells of Marscholko are considered by Mott to be derived from lymphocytes, and the morula cells to be degenerated cells of Marscholko.

As regards the origin of the lymphocytes, Mott considers that they may possibly be derived from the blood-stream, but are more likely formed by proliferation of the endothelial cells of the perivascular lymphatic space. According to Breinl, a layer of blood cells may be found external to the round cells, and hæmorrhages may be found in the cord. The ependyma of the lateral ventricle also shows a proliferation and dense fibrous formation at times. With regard to the parenchymatous elements, Mott considers that there may be increase in neuroglial nuclei and lymphocytes in the perineural spaces, while there is atrophy of the dendrons and diminution of the Nissl bodies, and alteration in the nucleus, which becomes large, clear, and eccentric. These changes are most marked in the cerebral cortex and medulla, and less so in the spinal cord. The cells of the posterior spinal ganglion, however, show chromatolysis. The central canal of the spinal cord may be dilated, but is more generally occluded by proliferation of the cells of the ependyma.

The next series of characteristic changes are in the lymphatic glands, in which trypanosomes are often found. These changes begin with a conversion of the lymphocytes into cells of Marscholko, and these, again, into morula cells The endothelial cells of the lymph sinus proliferate and take on a phagocytic action, containing lymphocytes, red blood cells, and chromatin particles. At the same time the gland becomes intensely congested, and the fibrous tissue of the capsule and septa proliferates, so that they and the walls of the lymph sinuses and of the vessels become thickened.

A lymph nodule therefore appears to be surrounded by a fine connective meshwork, containing few lymphocytes, but many red corpuscles and phagocytes. As time goes on the inflammation in the gland subsides, and it becomes less vascular, firm, and hard, and full of dense fibrous tissue. Secondary infection, however, may occur with the formation of abscesses.

Microscopically the lungs may be found to be hyperæmic, even when normal, to the naked eye, while the complication of pneumonia will give rise to the usual appearances. The heart shows a small-celled infiltration in all its layers, with sometimes hæmorrhages. The liver and spleen may show thickening of the capsule, while the latter is very congested, and its trabeculæ are increased in thickness. In natives signs of chronic malaria are almost constantly present in the spleen and liver. The bone-marrow may be very cellular, with congested vessels and hæmorrhages.

Symptomatology.—The course of the disease may be roughly divided into three stages—the incubation, the febrile stage, and the cerebral stage.

Incubation.—The duration of the incubation period is not certainly known in man, but it is considerably shorter than was believed by the old authors: probably it does not exceed two or three weeks, and, according to Martin and Lebœuf's observations in Europeans, it may be even less than ten days. The bite of the infected *Glossina* gives rise, as a rule, only to very slight local irritation, which quickly subsides, and is often overlooked by the patient.

Febrile Stage (*the so-called Trypanosome Fever*).—The onset of the disease is characterized by attacks of fever almost constantly associated in Europeans with an erythematous eruption. This fever lasts about a week, and disappears, to recur again later for the same or much longer periods. It is generally of an intermittent or remittent type. During an attack the pulse-rate and the respirations are increased, and there is often enlargement of the liver and spleen, though how much of this may be due to recurrent malaria is not known. Neuralgic pains and headache may also be complained of.

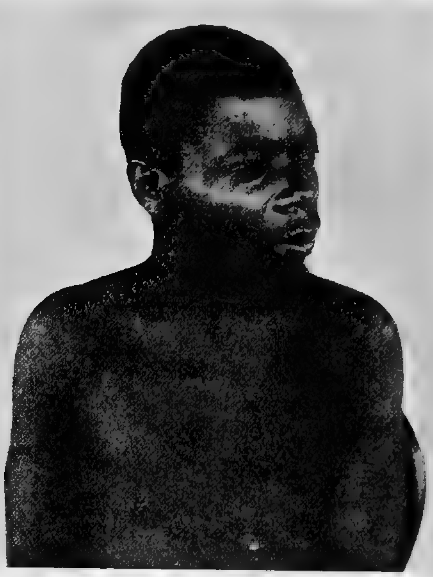

FIG. 298.—NEGRO PATIENT IN THE EARLY STAGE OF SLEEPING SICKNESS.

The erythematous eruption begins, as a rule, with badly defined, pinkish patches, which clear in the centre until a ring is produced; a portion of the ring fading off a crescent may be produced. This circinate eruption may appear on any part of the body, but is especially frequent on the trunk; in some cases, instead of rings, solid infiltrated patches, the size of a half-crown or larger, are present. Rubeloid spots are not rare. A vesicular-papular eruption has also been described, but is rare in our experience. Dermatographia is common in Europeans. In full-blooded negroes the erythematous eruption may not be noticeable; in them very often a dry, scaly condition of the skin is found. These various eruptions are called *Trypanides*.

The most typical sign of the disease in this stage is enlargement of one or more lymphatic glands, especially those in the posterior triangle (Winterbottom's sign). The enlarged glands are in this period generally fusiform, and of rather soft consistency. Another early symptom, noted by Kerandel, is a general intense, deep hyperæsthesia. As repeated attacks of fever increase, the patient may be anæmic and asthenic, but the febrile condition may last for years, and, indeed, in this stage the disease may be cured.

The Cerebral Stage (*the so-called Sleeping Sickness*).—After the febrile stage has lasted some time (weeks or months), a change begins to appear in the habits and disposition of the patient. Previously bright, intelligent, and hard-working, he becomes apathetic, dull, with a disinclination for exertion, preferring to sit quietly or to lie down. He also becomes careless in his work and dirty in his habits, and at the same time a difficulty in walking begins to be noticed. In this condition the sleeping-sickness stage of the disease may be said to have been properly entered. Typically, the patient is dull and apathetic, but can be easily roused, and answers questions rationally without difficulty in speech. Sleep may be excessive, but is not the prominent symptom so often described, the condition being more one of lethargy, from which the patient can be easily roused. Fine tremors are noticed in the tongue at first, later in the hands and arms, and sometimes also in the legs, and even in the abdominal muscles. The tremor of the tongue and hands may be a very early symptom. These tremors may occasionally be so severe that they cause the whole body to shake, and at times epileptiform fits, general or localized, may be seen. The gait is peculiar, there being apparently a difficulty in raising the feet, so that the patient shuffles along; but there is no paralysis as a rule, and the superficial reflexes are normal; the deep reflexes may be exaggerated and then lost, there is no clonus. There is inco-ordination in some cases, and Romberg's sign may be present. As the disease advances, rigidity appears, especially in the muscles of the neck and legs, which latter may assume the position of flexion of the thighs on the abdomen and the legs on the thighs. Babinski's sign is absent. Sensation is at first normal, but there may be hyperæsthesia in the region of the fifth nerve and other nerves, and at times the patient complains of headache. The pupils are equal, moderately contracted, and react to light and accommodation. There is nothing abnormal in the organs of special sense as a rule. There is usually fever, the temperature

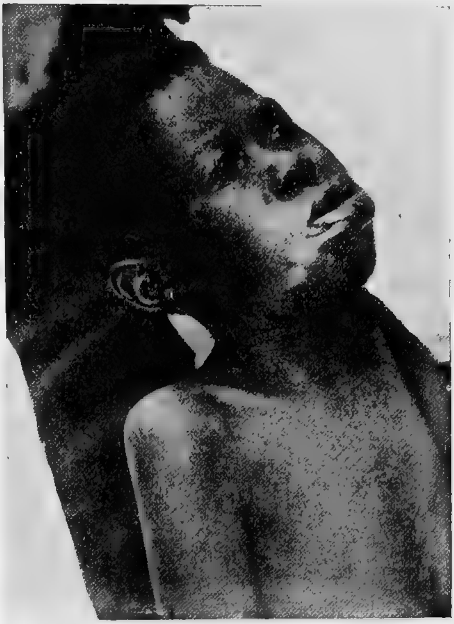

FIG. 299.—NEGRO PATIENT IN THE LATE STAGE OF SLEEPING SICKNESS.

rising in the evening from 100° to 104° F., and falling to subnormal in the morning; but this may be varied in many ways: thus for a period the temperature may be almost normal or subnormal, while for some days before death it becomes, as a rule, permanently subnormal.

There are no special symptoms, such as rigors or sweating, associated with the rise of temperature. The pulse is quick (90 to 140), but it is independent of the temperature, being quick with a low temperature. It is regular, but small and very low in tension, and generally is imperceptible at the wrist for some time before death. The heart as a rule shows no abnormal symptoms, though systolic inorganic murmurs may be present. The respirations are regular and equal, but are increased in number, especially towards evening, varying from 20 to 30; before death they not uncommonly take on the Cheyne-Stokes type. Congestion and œdema, with patches of pneumonia, are not infrequently met with before death. The appetite is good, and may even be increased; digestion is usually satisfactory, but constipation may be marked, or there may be occasionally diarrhœa. The tongue is frequently flabby and covered with white fur; the fæces of native patients are typical of a vegetable diet, and show the usual parasites of a tropical country. The spleen and liver may be enlarged, which perhaps may be due to malaria.

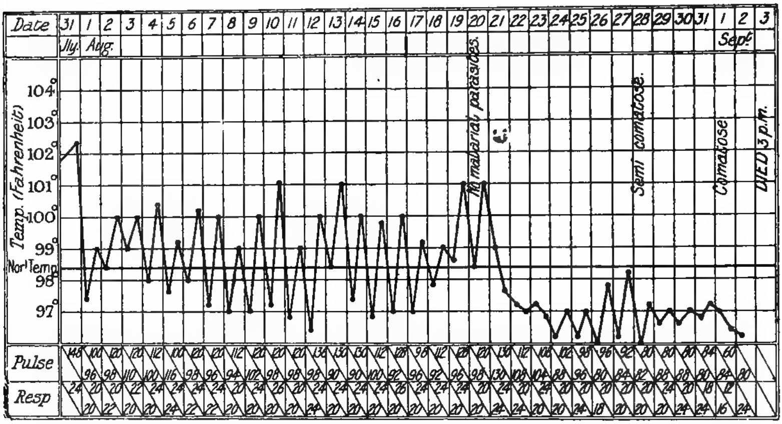

FIG. 300.—TEMPERATURE CHART OF A CASE OF SLEEPING SICKNESS.

From Low and Castellani Reports of the Royal Society on Sleeping Sickness.

The Blood.—The examination of the blood is complicated, because its condition is bound to be influenced by the secondary infection with other parasites, animal and vegetal.

With this understanding trypanosomiasis causes in a certain number of cases a gradual diminution of the red cells to 2,000,000 or less, with a corresponding decrease in the hæmoglobin, but it is to be noted that, as first observed by Nabarro in several cases, the actual number of erythrocytes may be above normal. The red cells are usually normal, but normoblasts may be seen. The leucocytes are normal in number, as a rule, with an increase of mononuclear cells, while there is a terminal polymorphonuclear increase before death.

In fresh preparations the red cells are not evenly distributed, nor do they form rouleaux, being generally clumped into masses. This phenomena of *auto-agglutination* was first noticed by Kanthack, Durham, and Blandford in the lower animals inoculated with nagana, and in man, in cases of sleeping sickness, by Dutton, Todd, and Christy, and may be of diagnostic value.

The chemical examination of the blood in trypanosome infections of animals has been performed by Takinioff and by Nierenstein, the latter of whom found, by Moore and Wilson's method of testing the alkalinity of the ash, that the acidity of the blood was increased, probably due to the formation of amido-acids, either secreted by the parasites or produced by their action upon the proteids of the serum. The acidity was tested by phenolphthalein and Congo red, and the alkalinity, which remained fairly constant, was tested by dimethyl-amido-azo-benzol.

The animals were infected with *T. brucei* and *T. equiperdum*, but so far no observations have been made on human blood.

Urine.—No abnormality is found in the urine, but the reaction, amount of phosphates, etc., of course, varies with the food taken. In native patients it is very often alkaline.

Sexual desire and menstruation are normal at first, but later are lost. The lymphatic glands throughout the body, but especially those of the neck, and more especially those of the posterior triangle, are enlarged. It is to be noted, however, that in the last stages the lymph glands often undergo a process of fibrosis, becoming smaller and harder. The skin becomes dry and rough, but may be perfectly normal, though a papulo-pustular eruption may be noted on the backs of the hands and forearms. Nutrition suffers, and the patient generally becomes much emaciated.

As the disease progresses the muscular weakness and emaciation become worse and worse, the tremors more pronounced, the saliva dribbles from the mouth, the urine and fæces are passed involuntarily, and bed-sores form, while the intelligence becomes more and more affected, and the patient passes into a state of coma, with a permanently subnormal temperature and an absence of pulse at the wrist, and in a short time is liberated from his sufferings by death. The duration of the cerebral or sleeping-sickness stage varies from a few weeks to several months.*

Complications.—The patient is often infected by parasites other than trypanosomes; thus, *Plasmodia* and *Laveraniac*, *Filariæ*,

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* Since the atoxyl treatment has become of general use, Hodges has noted that convulsive and mental symptoms are more prominent, and that death is often sudden, without being preceded by a period of coma.

Schistosomum mansoni, *Agchylostoma duodenale*, *Ascaris lumbricoides*, *Trichuris trichiura*, *Strongyloides stercoralis*, *Trichomonas intestinalis*, *T. vaginalis*, *Dermatophilus penetrans*, and *Amœbæ* may all be found. The commonest complication during the last stage is a cerebro-spinal meningitis, due to streptococci, pneumococcus, or meningococcus.

Pneumonia, laryngitis, and œdema of the glottis are not rare, while iritis is seen at times, and symptoms of mania, delirium, and epilepsy may frequently be observed.

Diagnosis.—In the first stage (trypanosome fever) the malady may be readily confused with malaria and other fevers; in the sleeping-sickness stage the diagnosis can often be made on clinical signs, but confusion may arise with cerebro-spinal meningitis and other nervous diseases. In our experience, the so-called 'Kerandel symptom' (general intense deep hyperæsthesia), the 'Low-Castellani symptom' (peculiar fine tremor of the tongue), the 'Winterbottom symptom' (cervical polyadenitis), may arouse, especially the last-named, a suspicion of trypanosomiasis, but are not sufficient to make a definite diagnosis, for which the demonstration of *Trypanosoma gambiense* in the body of the patient is necessary. The following methods should be used:

1. *Microscopical Examination of the Peripheral Blood from the Finger or Ear.*—This procedure is often a failure, even using thick films.

2. *Scarification of the Erythematous Eruption and Examination of Blood Films.*—This method is more useful than the first, but may fail.

3. *Nabarro's Method.*—Repeated centrifugalization of 10 c.c. of citrated blood, and examination of the third sediment. The results are good.

4. *Dutton-Todd's Method.*—Some citrated blood is centrifugalized in small tubes and the leucocytic layer examined for trypanosomes.

5. *Greig-Grey's Method.*—Aseptic puncture of the enlarged cervical glands, with a sterile syringe. The gland-juice is examined for trypanosomes. This, from a practical point of view, is the most valuable method. To Mott belongs the credit of having first suggested the search of trypanosomes in the lymph glands as a diagnostic method.

6. *Castellani's Method.*—Centrifugalization for fifteen minutes of 10 c.c. of cerebro-spinal fluid, aseptically removed by means of lumbar puncture. The sediment is examined for trypanosomes, by making fresh and stained preparations. The result is almost constantly positive in the sleeping-sickness stage, but negative, as a rule, in the trypanosome-fever stage.

The technique to perform lumbar puncture is as follows: The patient may be given chloroform, but usually a local anæsthetic spray is sufficient. Lay the patient on the right or left side; flex the thighs on the abdomen. Then make the skin of the lumbar region aseptic, and, feeling with the tip of the finger the position of the laminæ, thrust the sterile needle between the laminæ of the third and fourth lumbar vertebræ, ½ inch from the median line, obliquely outwards and forwards into the canal. The fluid will escape, and can be collected in a sterile tube. After withdrawing the needle, the area should be covered with an aseptic pad and bandage.

7. *Inoculation of Susceptible Animals.*—Ten c.c. or 20 c.c. of blood are aseptically removed from a vein, and inoculated into susceptible animals. The animals most suitable are monkeys, guinea-pigs, and dogs. The most suitable monkeys, according to Thiroux and D'Anfreville, are those of the species *C. ruber*, while some other species—*e.g.*, *C. fuliginosus*—are almost refractory.

Prognosis.—The prognosis is serious, but not quite so serious as it was before the introduction of atoxyl. If the patient is in the early stage, and can be removed from the endemic area and put under good hygienic conditions, and atoxyl treatment, the disease may be cured, or at least a marked improvement may be obtained. Great care, however, is necessary before saying that a patient is really cured, and at least two blood injections into susceptible animals should be performed before giving a decided opinion. If, however, the patient is compelled to live in the endemic area, and cannot be treated with atoxyl, the outlook is most hopeless.

Treatment.—The only treatment which so far has been found to be of any real benefit is by arsenic, and the form in which this is applied at the present time is the compound called atoxyl. We recommend Manson's method of administration—2 to 3 grains of atoxyl by intramuscular injection every second or third day for at least two years; or Broden and Rodhain's method—7½ grains of atoxyl by intramuscular injection every fifth day. Koch recommends the subcutaneous injection of 7½ grains (½ gramme) on two successive days every ten days for two months, when the treatment is to be stopped until further symptoms develop, and when this occurs the treatment should be repeated. The drug can be obtained or imported from any chemist in sterile vials ready for hypodermic medication. The injection of atoxyl is occasionally followed by a febrile reaction, due, according to some observers, to the absorption of products of trypanolysis.

Owing to the fact that large doses of atoxyl lead to such unpleasant results as optic atrophy, gastro-intestinal inflammation, and peripheral neuritis, other arsenical preparations have been recommended; and the firm Burroughs and Wellcome has introduced, under the trade name of soamin, a preparation somewhat similar to atoxyl, but less poisonous. It is given in the same doses as atoxyl.

Ehrlich has prepared a derivative of atoxyl, called arseno-phenylglycin, which is from two to four times less toxic than atoxyl itself. This preparation has been tried by Ehrlich, Mesnil, Kerandel, and others upon lower animals experimentally infected with *Trypanosoma gambiense*, and has been found to be very effective being also a prophylactic. It has been used in man by Kleine with good results in the same doses as atoxyl.

When for special reasons it is impossible to carry out the treatment by injections, arsenic may be given by the mouth in the form of Fowler's solution, which must be given in 5-minim doses, and gradually increased to 15-minim doses.

Löffler and Rühs' neutral solution of arsenious acid (1 c.c. of which contains 1 centigramme of arsenious acid) may be given in doses of 2 c.c. daily for three days, and then continued in doses of 1 c.c. per diem for several weeks, after which it must be temporarily discontinued, but must after a time be restarted, and in this manner continued for months, provided no ill-effects are produced.

Atoxyl is sodium-*p*-aminophenyl arseniate,—$\mathrm{NH_2C_6H_4AsO}\left\langle\begin{matrix}\mathrm{ONa,}\\ \mathrm{OH}\end{matrix}\right.$ and contains from 25·95 to 20·78 per cent. of arsenic, according to the amount of water of crystallization. Mono-acetylated atoxyl is $\mathrm{CH_3CONHC_6H_5AsO}\left\langle\begin{matrix}\mathrm{ONa}\\ \mathrm{OH}\end{matrix}\right.$. *Soamin*, according to the published formula, is $\mathrm{C_2H_4NH_2AsO(OH)\ (ONa)\ 5H_6O}$.

According to Mesnil and Nicolle observations, and the more recent observations of Nierenstein, it is not the arsenic in these compounds which is to be looked upon as the effective agent, but the amido-group, which may possibly be the effective agent in trypan red, afridol blue, afridol violet, and parafuchsin, which do not contain arsenic, but possess amido-groups, and affect trypanosomes in a similar manner to atoxyl. According to Ehrlich, Levaditi, and Yamanouchi, atoxyl undergoes a reduction in the animal tissues. Ehrlich has prepared two derivatives of atoxyl, one of which, already mentioned (arsenophenylglycin), is very effective in mice on atoxyl-resistant trypanosomes. Levaditi and Yamanouchi have also prepared an active derivative of atoxyl, which they call trypanotoxyl. Uhlenluth has recently recommended atoxylate of mercury.

Combined Therapy.—As the result of the important observations of Erhlich on the phenomenon of chemo-resistency, which may be acquired by trypanosomes after a long use of the same drug, numerous combined treatments have been suggested. Of these, the most important are : (1) antimony and atoxyl ; (2) mercury and atoxyl ; (3) orpiment and atoxyl ; (4) various dyes and atoxyl.

Antimony and Atoxyl Treatment.—Antimony salts, as well as phosphorus, were first suggested by Mesnil as likely to be of use in trypanosomiasis. To Plimmer and Thomas belongs the credit of having experimentally shown the powerful trypanocide action of antimony. In man the subcutaneous or intramuscular injections of the various salts of antimony (sodo-tartrate of antimony, sulphide of antimony and soda, etc.) are very painful. Manson therefore gives the drug by the mouth, and other authors by intravenous injection. Apparently the trypanocide action of antimony is more powerful in the lower animals than in man, in whom the results are inferior to those given by atoxyl. A mixed antimony and atoxyl treatment is, however, of advantage in some cases, an atoxyl injection (3 grains) being given every third day, or 7½ grains every fifth day, and sodio-tartrate of antimony (Plimmer's salt) administered daily—2 grains dissolved in a large quantity of water (2 pints). Tartar emetic may be given by intravenous injections, using solutions of 1 in 100 or 1 in 1,000. The dose of the drug to be given is 5 to 10 centigrammes per injection. It is important that none of the fluid of the injection should escape into the surrounding tissues, as a violent inflammation may result. These injections should be administered monthly on ten consecutive days for a long period. The injection of salts of antimony may produce a marked fall in the blood-pressure, dyspnœa, and signs of collapse, and therefore Thiroux suggested that injections of caffein should precede their administration. To prevent the irritation caused by injections of watery solutions of tartar emetic, Plimmer has advised the use of antimony suspended in sterile olive oil.

Mercury and Atoxyl.—Mercury was first introduced in 1902 for the treatment of sleeping sickness by Low and Castellani, using intravenous injections of Baccelli's sublimate solution,[*] in association with arsenic and quinine by the mouth. A fall of the temperature was observed in some cases, but the fatal course of the disease was not influenced. Moore, Nierenstein, and Todd have used mercury and atoxyl in combination or alternation, with the idea that mercury might act upon the latent form of trypanosome, while atoxyl would influence the active form. In man this combined treatment has apparently not given any better results than atoxyl alone.

Orpiment and Atoxyl.—This combined treatment, consisting of atoxyl and an inorganic salt of arsenic such as orpiment, has been recommended by Laveran and Thiroux, and has already been used in man with good results. The orpiment should be given in pills, in the dose of 2 grains of orpiment two or three times daily. The administration of orpiment frequently causes diarrhœa. Thiroux therefore incorporates in the orpiment pills some opium. Thiroux's formula is :

Orpiment	20 grammes
Extr. opii	0·40 gramme
Gumm. ..	q.s.
Pulv. glyceriz.	

To be divided into 200 pills.

Various Dyes and Atoxyl.—Combined treatments of Mesnil's afridol and atoxyl, Ehrlich's parafuchsin and atoxyl, picric acid and other dyes and atoxyl, have been suggested, but in man the results have not been so successful as in the lower animals.

In addition to the atoxyl treatment or combined treatments malaria and the intestinal parasites must be treated if present. The patient should, if possible, be removed from the area of infection and placed under good hygienic conditions and on good food, and no case should be considered to be cured until the injection of the blood, on more than one occasion, into susceptible animals fails to infect them.

Prophylaxis.—At the present time prophylaxis must be undertaken on the assumption that the disease is spread from place to place by man along channels of human intercommunication, and from man to man by *Glossina palpalis*. With regard to the fly, further information is required as to its bionomics, though Bagshaw's and Hodges' researches, as well as those of Zupitza, Sander, and Minchin, have thrown some light on the subject.

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Hydrargyri perchloridi	0·10 gramme
Sodii chloridi	0·50 gramme
Aquæ destillatæ	100·00 c.c.

1 to 4 c.c. per intravenous injection.

Before enumerating the principal prophylactic measures to be recommended, we wish to draw attention to the fact that these, as pointed out by Bagshawe, will be useless without the co-operation of the natives. This co-operation may be obtained by explaining to them at every possible opportunity the reason for the measure taken. In this missionaries and native chiefs may be of the greatest help. With this proviso we consider the following to be the principal prophylactic measures :

1. The different Governments should be invited to co-operate to prevent persons travelling from districts where the disease exists into non-infected regions, and medical posts of inspection should be established for the examination of natives. According to some authorities (Dutton, Todd), all natives presenting enlarged glands should be considered, from a practical point of view, as trypanosome carriers, and prevented from emigrating. This is, perhaps, going a little too far, inasmuch as, in our experience, and in that of Low, Bagshawe, Koch, Hodges, etc., numbers of natives have enlarged glands, though not suffering from trypanosomiasis ; and, on the other hand, cases of trypanosomiasis occur in which there is no enlargement of the lymphatic glands. We admit, however, that gland palpation may be of some use in formulating an approximate idea of the extent of the dissemination of the disease.

2. The sick should be removed from the fly-belts, and segregated in places where the *Glossina palpalis* is not found. They should be treated with atoxyl before being moved.

3. Villages should be removed, if possible, from the fly zones, and the occupations carried on in fly zones, such as fishing, should be discouraged.

4. Clearing of the bush along the water's edge for 100 yards, and round a village for 300 yards at least.

5. European bungalows should be segregated from native quarters. Houses should be rendered gnat-proof, and natives bringing water from streams should not be allowed to enter the house, as they are liable to be surrounded by tsetse-flies which have followed them. Indeed, some authorities look upon the bath-room as a source of European infection.

6. Natives in the fly zones should be encouraged to wear suitable clothing, and the reason explained to them. Europeans should be careful not to expose their legs and hands to be bitten. High boots, puttees, or leggings should be worn, and where the fly abounds gloves and veils, though very uncomfortable, are of service. White clothes are better than dark ones, as it has been long observed that the tsetse-fly, as well as many other insects, have a preference for black or dark colours. The use of volatile substances such as citronella oil has been advised by some. Unfortunately, the odour of such substances is repellent to many persons.

7. Destruction or the animals on which the fly feeds ; destruction of the pupæ. Koch has recommended the destruction of the crocodiles by poison, and by collecting and destroying their eggs.

Unfortunately, the crocodile is not the only animal on which the fly feeds. The blood of many other vertebrate animals is palatable to the fly, and therefore this method of prophylaxis is without much practical importance.

Minchin has suggested the breeding of the jungle-fowl to destroy the pupæ, which, as discovered by Bagshawe, are found in the turf among the roots of banana and other trees. Further information, however, is necessary on the enemies of the pupæ and adult tsetse-flies.

South American Trypanosomiasis.

Synonym.—Opilaçao.

Definition.—South American trypanosomiasis is a chronic specific disease caused by *Trypanosoma cruzi* Chagas 1909, and spread by a bug belonging to the genus *Conorhinus* of the family *Reduviidæ.*

History.—In February, 1909, Chagas reported that he had found a new trypanosome, which he named *T. cruzi*, frequently in the intestine of a species of Conorhinus, which occcurred in the State of Minas in Brazil. He also reported that he was able to infect marmosets, dogs, cats, guinea-pigs, and rabbits by the bites of the infected insects, and also to grow the parasite on blood-agar.

In May, 1909, he announced that he had made an investigation of the mines of the State of Minas, and found the Conorhinus in large numbers in the houses of the poorer inhabitants. He noticed that the bite was painful, and that the insect was very voracious, and also that it generally attacked people, especially children, at night, biting the face, from which fact the inhabitants called it 'barbeiro' or 'barber.'

He suspected this Conorhinus of causing a disease marked by extreme anæmia, which occurred especially among the children, and he was able to find in the blood of a two-year-old child during an attack of fever a trypanosome identical with *T. cruzi* morphologically and biologically.

Geography.—At the time of writing the disease is only known among the poorer inhabitants of the State of Minas in Brazil.

Ætiology.—The disease is caused by *Trypanosoma cruzi* Chagas 1909. This trypanosome, which is remarkable because of the large size of its kinetonucleus, is capable of being transmitted by a species of Conorhinus to domestic animals and man.

In the domestic animals it can be found free in the liquor sanguinis. The life-history would appear to resemble in some details that already described by Breinl, Hindle, and Moore for *T. gambiense*, as Chagas found non-flagellate round forms composed of eight small trypanosomes in the bugs. Each of these organisms contained a bilobed nucleus, and when the mass broke up, was seen to penetrate into a red blood cell, in which it became a typical trypanosome, and out of which it grew, and finally escaped as the full-grown trypanosome.

In the blood three forms are seen: the first with a large nucleus and loose chromatin and a terminal kinetonucleus; the second narrower, with an oval nucleus and dense chromatin; the third with a long nucleus.

In the bug the trypanosome loses its undulating membrane and flagellum, while the kinetonucleus approaches the trophonucleus, and the parasite becomes encysted. Crithidial-like forms are found in large numbers in the proctodæum. In the cœlom of the bug typical adult trypanosomes can be found.

Pathology and Morbid Anatomy.—At the time of writing there is no description of the pathology and morbid anatomy.

Symptomatology.—The disease is characterized by extreme anæmia, wasting, and stunted development in children, associated with attacks of remittent or intermittent fever, œdema of the eyelids and other parts of the body, glandular enlargement, especially in the neck and axilla, and splenic hypertrophy. The trypanosomes are found during an attack of fever in the peripheral blood, but not in the apyretic interval.

Diagnosis.—The diagnosis must be effected by finding the parasite in the blood during a febrile attack. The disease is most likely to be confounded with agchylostomiasis, from which it can be recognized by the absence of the typical ova in the fæces and the presence of *T. cruzi* in the blood, though, of course, both infections may occur together.

It might also be mistaken for malaria during the febrile attack, especially as there is splenic enlargement, but the absence of the malarial parasite and the presence of *T. cruzi* in the peripheral blood will enable a diagnosis to be made.

Prognosis.—Very little can be said as regards the prognosis at present. Children and infected animals are known to have died of the disease.

Treatment.—The indications for treatment are the same as those for African trypanosomiasis.

Prophylaxis.—The prophylaxis must aim at the prevention of the Conorhinus biting man.

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CHAPTER XXIX

DENGUE

Synonyms — Definition — History — Climatology — Ætiology — Pathology— Symptomatology — Diagnosis — Prognosis — Treatment — Prophylaxis — References.

Synonyms.—Febris Endemica cum Roseola, Exanthesis Athrosia, Knokkelkoorts, Arthrodynie, Fièvre Rouge.

There are upwards of one hundred known synonyms for this fever, many of which refer to it as a form of rheumatism, or give it fanciful terms, such as ' breakbone ' or ' breakheart,' ' broken wing ' or ' giraffe fever.' It is sometimes called ' three days' fever,' a term by which a quite different disease is also known.

The word ' dengue ' is said by Vambery to be of Arabic origin, and to mean weakness, but it might equally be of East African, Indian, or Spanish origin.

Definition.—Dengue is an acute specific non-contagious fever of unknown causation, characterized by two febrile paroxysms, separated by an intermission or remission, without jaundice, albuminuria, or hæmorrhages, and with a marked leucopenia, and a pulse which varies directly with the temperature. It is spread by the agency of *Culex fatigans* Wiedemann.

History.—It appears to have been first recognized at Batavia, in Java, in the year 1779, by Bylon, though it may have been noted by Pazzio previous to this in 1764-68 in an epidemic in Seville. It was soon discovered in other places, being found from 1779 to 1780 in Egypt, Arabia, Persia, and North America, and in 1784 in Spain, to which it appears to have come from the West Indies, and in 1818 in Peru. In 1824-28 it occurred all over the tropical and subtropical zones, and in 1830-70 it formed a series of large and small epidemics in the same regions. From 1871-73 there was an epidemic implicating East Africa, Egypt, Arabia, India, Burma, Indo-China, and China, and spreading later to America and North and West Africa—*i.e.*, practically to all the tropical regions. In 1876-88 it was epidemic in Hong Kong, Egypt, Syria, and the Mediterranean, and in the Fiji Islands in 1885, to which it was conveyed by a European suffering from the complaint. In 1889 it was especially prevalent in Asia Minor, Turkey, and Greece.

From 1890 to 1895 there were outbreaks in Senegambia and Hong Kong. From 1895-96 there were epidemics in Bombay and in Charleston. In 1897-98 it was epidemic in Georgia, Florida, and Texas. In 1901 it occurred in Penang and Asia Minor; in 1902 in Hong Kong, Singapore, Madras, Rangoon, and Upper Burma. In 1906 it occurred in Saigong on a French warship, and recently it has been prevalent in Singapore. Manson says that an epidemic or pandemic takes place about once in twenty years.

The discovery of the disease, therefore, appears to have been first made by Pazzio and Bylon, and the first full clinical description by Dickson in 1828.

The first attempt to find a causation for the disease was by McLaughlin in 1886, who found micrococci in the blood, but this was disproved by Klein, Wright, Crookshank, and Macfadyen. In 1903 Graham stated that he had observed small hyaline, unstainable rods or dots in the red blood-corpuscles, which he considered to be protozoal parasites of the nature of Plasmodia. This discovery has been refuted by Carpenter and Sutton, Guiteras, Agramonte, Kiewiet de Jonge and Hahn, Still and Ashburn, and Craig. Graham fed *Culex fatigans* Wiedemann on patients suffering from dengue, and claimed to have found his parasites in these mosquitoes up to the fifth day after feeding. He did not find any oökinetes or oöcysts, but he says he found spores in the cells of the salivary glands of the mosquitoes from forty-eight hours to one month after they had fed on infected blood. Further, he states that he caused a typical attack of dengue by injecting subcutaneously a solution, in normal saline, of the salivary glands of a mosquito, which had bitten a dengue fever patient twenty-four hours previously. He only performed one experiment, because the illness caused was very severe, but he succeeded, after an incubation of four to six days, in infecting healthy people by the bites of mosquitoes (*Culex fatigans*) fed on dengue-fever patients.

Though Ashburn and Craig (in 1907) have not supported Graham by finding the parasite, they have supported him, as will be presently described, by proving that a typical attack of dengue can be produced by the intravenous inoculation of filtered and unfiltered blood from an infected patient, and that the disease can be, and usually is, transmitted by the bite of *Culex fatigans* Wiedemann.

Climatology.—The history of the disease indicates roughly its geography, which lies mostly in the tropics, but can extend to the subtropical zones. Its usual boundaries are 32° 47′ N. and 23° 23′ S., but during warm weather it may spread to 36° 10′ N., and even to 42° N. exceptionally. It is, therefore, a disease of tropical climates, and of warm weather in other climates. It appears to be favoured by low-lying lands well supplied with water, and not to be found at high altitudes; but there are exceptions to this.

When the distribution of dengue is compared with that known for *Culex fatigans*, it will be seen that the two coincide most remarkably. In fact, at the present time it appears as though the geographical distribution depends upon the distribution of that insect, together with the importation or presence of infected persons.

Ætiology.—We are entirely indebted to Graham and Ashburn and Craig for our knowledge of the ætiology of this disease.

There appears to be no doubt that dengue fever is caused by some unknown living organism which requires over two days to increase so as to produce the symptoms of the disease when inoculated into human beings.

This organism exists in the blood, as can be shown by the intravenous injection of 20 c.c. of dengue-fever blood producing typical attacks of the disease, the incubation usually being two to three days; but it is so small that it will pass through the pores of a filter which will retain *Micrococcus melitensis*, which is only 0·4 μ in diameter, as is demonstrated by the production of the disease by intravenous injections of filtered dengue-fever blood, the incubation being two to three days, as before.

The organism can be transmitted by the bites of *Culex fatigans*, which appears to be the principal agent in the spread of the disease, the incubation period being about three days sixteen hours. Further, there is a natural immunity against the disease in some people, and also some degree of acquired immunity of unknown duration obtained by an attack.

The points in the ætiology which require further research are the nature of the organism and its chemical products; the changes, if any, which the parasite undergoes in the mosquito; the length of time in which the mosquito can carry the infection; whether any mosquito other than *Culex fatigans* can spread the disease; and how long the acquired immunity lasts in man. In conclusion, it may be said that there is no evidence of infection other than by the bite of the mosquito.

Pathology.—There is but little that can be written on this subject, as the cause of the disease is unknown, and therefore, of course, its action cannot be explained.

Morbid Anatomy.—This appears restricted to the description of the complication which killed the person—viz., peritonitis or pleuritis.

Symptomatology.—The incubation period, judging from experimental infection by mosquito-bites, varies from three to six days. Prodromata are usually absent, but general malaise may be felt during a period not exceeding three days before the onset.

The attack is usually sudden, and introduced by severe pain in some part of the body, or merely by the sensation of extreme fatigue, or by chilliness and shivering, or by deep flushing of the face. In children, convulsions or delirium may usher in the illness. In any case the temperature rapidly rises, the pulse quickens, and the skin and mucosæ become markedly congested, especially about the face, mouth, and throat. The conjunctivæ are injected, the eyes watery, and sometimes vomiting and purging are also present. The disease now progresses for one, two, or three days, after which there is, as a rule, a remission or an intermission.

During this period the temperature rises to 103° F. to 106° F., and the pulse increases proportionately with the temperature to 90 to 140 per minute. Severe pains in the head, and especially in the eyeballs, are experienced, and, in addition, pains in different parts of the body, especially in the lumbar region and the legs. Often the joints are painful, usually without any sign of redness or swelling. This pain in the joints appears really to be due to the muscles in the neighbourhood, as the joint can often be passively moved without pain, while active movement induces almost agony. There are, however, rare cases in which the joints are affected, as is shown by redness and swelling. As regards the alimentary canal, the tongue is moist, but becomes covered with a white creamy fur. There is no appetite, nausea and vomiting are not uncommon, and constipation or diarrhœa may be present. The lymphatic glands are not enlarged. The circulatory system is not affected, except that fainting occurs at times, while a sensation of præcordial discomfort or of suffocation may be complained of. Insomnia and delirium are not infrequent, but meningitis and neuritis must be uncommon if they occur at all, though hyperæsthesia of the skin may be observed. The skin shows the congestion already mentioned, which is not always present, being at times replaced by the opposite extreme of pallor. Jaundice, if it occurs, is rare. Hæmorrhages are rare, and will be mentioned as a complication. The changes in the blood have been carefully worked out by Ashburn and Craig, The erythrocytes are usually normal in appearance and number. but a few poikilocytes may be seen, while the hæmoglobin and colour-index are also normal. Leucopenia is so constant as to be of diagnostic importance, varying from 4,860 to 1,200, the average being 3,800 per cubic millimetre. The leucocytes are normal in appearance, but there is a marked increase of the small lymphocytes and a decrease in the polymorphonuclear leucocytes. The urine appears to be usually quite normal, except that it is high-coloured, but may contain a minute trace of albumin, and in severe cases Guiteras says the diazo-reaction can be obtained.

On the third day the temperature usually falls rapidly to normal. This fall may be accompanied by the usual signs of a crisis—namely, profuse perspiration, the passage of much urine, violent diarrhœa, and bleeding from the nose—but in many cases these signs may be absent. The patient now feels better, except for slight pains, and a genuine intermission in the disease is established. In other cases, however, this intermission may be entirely wanting, and the temperature may only remit, remaining at 100° F. to 102° F.

The intermission or remission lasts until the fifth day of the illness, when the second attack begins with a rise of temperature to some point usually below 103° F., and at the same time a rash appears on the palms and backs of the hands, and rapidly spreads to the arms, the trunk, and the legs. This rash may be of two types—a measly eruption of small, circular, dark red papules, which almost entirely disappear on pressure, or a scarlatiniform eruption of close-set, bright-red points, which may coalesce and form large red patches. Eruptions intermediate in appearance between these two types may, however, be present.

The rise of temperature may last from a few hours to a day, and generally declines by crisis, with or without perspiration, on the sixth day. The skin eruption usually lasts from two to eight days, after which there is a desquamation, which may continue for two to three weeks.

The typical disease shows a first attack, an intermission, and a second attack, though the two attacks may become merged together. The typical rash may be absent, and sometimes the disease is so mild that it ends on the third day with the first crisis.

Convalescence may be quick and permanent, but, on the other hand, it may be protracted and complicated with sequelæ.

Complications.—The rarity of the symptom of hæmorrhage may perhaps justify its mention as a complication. It takes place from the mucosæ, as already mentioned, of the nose, stomach, intestines, and uterus. Hyperpyrexia may occur as a complication, but is rare, and pleurisy, pericarditis, orchitis, endocarditis, and meningitis sometimes complicate the disease and alter its characteristics.

Sequelæ.—The most important sequelæ are the pains in the joints and muscles, which worry patients considerably. Relapses are said to take place, but Ashburn and Craig doubt whether any occur a short time after an attack, as the persons who were supposed to relapse, in their experience, really suffered from malarial fever; for, as a matter of fact, there is an acquired immunity for some little time after an attack which prevents such relapses.

Diagnosis.—The diseases most likely to be mistaken for dengue are yellow fever, malaria, influenza, scarlet fever, measles, rheumatic fever, smallpox, and tonsillitis.

Yellow fever is recognized by its slower pulse, jaundice, and hæmatemesis; malaria by its blood parasites; influenza by the absence, as a rule, of any eruptions and the presence of catarrhal symptoms; scarlet fever by the presence of the sore throat with enlarged cervical glands; measles by the catarrhal symptoms and the absence of the severe pains; rheumatic fever by the swelling of the joints; smallpox may be with difficulty recognized until the eruption comes out; and tonsillitis may be recognized by examining the throat.

Prognosis.—This is quite good, as the mortality is usually nil, but in Australia it caused one death in 1,000 cases, principally in those under five and over sixty years of age.

Treatment.—No rational treatment can be given, as we do not know what the nature of the cause will prove to be. Symptoms must, however, be relieved. The fever and headache may be combated with cool sponging and cool applications; the pains by hypodermic injections of morphia or doses of Dover's powder ; this will also relieve the nervous symptoms, which otherwise will require bromides. Antipyrin, phenacetin, and aspirin, may be administered with care, and the bowels should be opened by calomel. The diet must be low, and stimulants should not be given.

Prophylaxis.—Protection against mosquitoes, as described under Malaria, excluding, of course, quinine prophylaxis, is the correct method of preventing the disease.

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CHAPTER XXX

YELLOW FEVER

Synonyms—History—Climatology—Ætiology—Pathology—Symptomatology—Diagnosis—Prognosis—Treatment—Prophylaxis—References.

Synonyms.—Febris Flava, Pestis Americana, Typhus Icteroides, Bilious Remittent fever, Fièvre Jaune, Gelbfieber, Febbre Gialla, Fiebre Amarilla.

Definition.—An acute specific non-contagious fever of unknown causation, characterized usually by two paroxysms of fever, separated by a remission or intermission, and accompanied with albuminuria, jaundice, and hæmorrhages, with usually a normal number of leucocytes and polymorphonuclear leucocytes. It is spread by the agency of *Stegomyia calopus* Meigen 1818 (synonym, *S. fasciata* Fabricius 1805, *non* Villiers 1789).

History.—Yellow fever is believed to have originally been a disease of the Antilles, and to have attacked the troops of Christopher Colombus in 1495 in the Isle of Spain (St. Domingo), from which it was carried by the Spaniards to the mainland of America. The endemic home of the disease at the present time is the east coast of Mexico, and Central America from Cape Tampies to Cape Gracias à Dios, and the Greater and Lesser Antilles. From this area it can spread by ships to various parts of the world, where it may become epidemic.

The first clearly-written description of yellow fever is that by P. du Tertre, in Guadaloupe, in 1635, but it soon became well known from the epidemic in Cuba in 1648-49; Jamaica, 1655; San Domingo, 1656; Martinique, 1688; and Vera Cruz, 1690. In 1698 it was recognized that the disease was being carried from place to place by ships, and a quarantine ordinance was brought into force, which lasted from 1709 till 1790, when the extensive wars of the period caused it to be ineffective, with the result that between 1791 and 1815 most extensive epidemics took place, and gave ample opportunity for the study of the disease. In 1794 Drysdale, of Baltimore, in 1797 and 1805 Rush, in Philadelphia, and in 1802 Vaughan, in Wilmington, drew attention to the large numbers of mosquitoes and other insects which abounded in their respective towns during yellow-fever epidemics, though rare in preceding years. In 1848 Nott, of Mobile, accused some insect or mosquito of being the possible carrier of yellow fever. In 1876 Dowell, of Galveston, showed that mosquitoes and yellow fever obeyed the same natural laws, and in 1878 it was demonstrated in Mobile that quarantine of the patients, together with sulphur fumigation, could control the epidemic. But it was not till 1881 that Charles Finlay, of Havana, directly attributed the spread of the disease to the mosquito. In 1882 Gererd, having caused a mosquito to suck the blood of a patient on the fourth day of the fever, then allowed it at once to bite his hand, with the result that he developed in due course a mild attack of yellow fever. The credit of having supported the mosquito theory for many years in numerous publications belongs to Finlay.

In 1883 Freire of Rio de Janeiro thought that he had discovered the cause of the disease in the shape of a micrococcus, and later C. Valle, C. Finlay, and Gibier each described specific bacteria. Sternberg studied the disease for years, but could find no definite bacterial or other cause. He, however, in a certain number of cases, came across a bacillus, which he called ' X.' In 1897 Sanarelli announced that he had found a bacterium (*Bacillus icteroides*) which he believed to be the cause of the disease, and, further, he prepared a serum for its treatment. Sanarelli's findings were at first confirmed by a large number of observers.

In 1900 Reed and Carroll announced that *Bacillus X* belonged to the colon group of bacteria, and *B. icteroides* to the hog-cholera group, and was probably identical with *B. choleræ suis*. In our experience *B. icteroides* is not identical with *B. choleræ suis*, but is a distinct species, although it plays no part in the ætiology of the malady, and is merely the cause of a secondary infection. In the same year Reed, Carroll, Agramonte, and Lazear proved that the disease could be produced by the subcutaneous injection of infected blood into a non-immune person; that the disease was not contagious, and was only spread by the bites of *Stegomyia calopus*. The agency of the mosquito was speedily confirmed by Guiteras, Ribas and Lutz, Marchoux, Salimbeni and Simond, Parker, Beyer and Pothier, and later by Rosenau, Parker, Francis and Beyer.

In 1903 Parker, Beyer, and Pothner concluded that the ætiological cause was *Myxococcidium stegomyiæ*, found in infected mosquitoes, which they believed to be an animal parasite closely resembling a *Coccidium*. Carroll, however, refuted this, as did Marchoux, Salimbeni and Simond, and finally Rosenau, Parker, Francis and Beyer clearly proved that *M. stegomyiæ* was a yeast normally found in mosquitoes. In 1905 Rosenau, Parker, Francis and Beyer showed that the disease could be communicated by the inoculation of infected blood filtered through the closest-grained Pasteur-Chamberland B filter which they could obtain, and therefore came to the conclusion that the causal agent of the disease must be of ultramicroscopic size.

In 1909 Seidelin described the presence of ring-like structures in the red cells of persons suffering from yellow fever, and Stimson a spirochæte (*S. interrogans*) in the tissues.

In the meanwhile the theory of the propagation of the disease by *Stegomyia calopus* has been put to the practical test of prophylaxis with most excellent results in Havana, Texas, Mexico, and New Orleans, and recently in the works of the Panama Canal.

It is impossible to close this history without drawing the reader's attention to the great benefit conferred upon mankind by the labours of Reed, Carroll, Agramonte, and Lazear, the last-named dying from yellow fever following an experimental bite of an infected mosquito.

Climatology.—As already stated, the endemic area includes a portion of the Atlantic coasts of Mexico and Central America, as well as the Antilles. There is no evidence that the disease is really endemic in West Africa, and still less in Central Africa, though in the former area it is not uncommon at times. On the contrary, there is evidence that the Cape Verde Islands were infected in 1510-15, and that the Gulf of Benin received its yellow fever from this source in 1520.

From the endemic centre the disease can spread by the agency of ships until it reaches 46° 56′ N. (Quebec) and 34° 54′ S. (Monte Video), which correspond to the isotherm of 60° F. (16° C.) for the mean temperature of the hottest month of the year. At its northern limits the disease is generally very mild, but at its southern limits it may be very severe.

The areas most usually affected are the Atlantic coasts of North America, as far north as Charleston (32° 46′ N.), and of South America as far south as Rio de Janeiro (22° 54′ S.). Another region commonly affected is the West Coast of Africa, from Senegambia to Saint Paul de Loando.

Europe has frequently been attacked—*e.g.*, England (Swansea) in 1865, France in 1861, Spain and Portugal in the eighteenth and nineteenth centuries, the last infection being in Madrid in 1878, and Italy (Leghorn) in 1804.

The disease has apparently more than once reached the Pacific, for it spread in 1740 to Guayaquil, in Ecuador, and in 1854 to Peru.

The distribution corresponds with that of *Stegomyia calopus*, and the fact that the disease is endemic in warm climates and more marked in the hot season, while it disappears in the winter of temperate climates, reappearing in the summer, coincides with the habits of the mosquito. Further, the facts that it is carried by infected ships and that it may affect low-lying regions near the coast, particularly ports, in which the dwelling-houses are especially attacked, are explicable by its mosquito transmission.

Ætiology.—The causal agent exists in the blood of an infected person, as can be proved by the fact that the subcutaneous inoculation of 0·1 c.c. of the infected blood into non-immune persons produces attacks of the disease, but it cannot be spread to man by post-mortem wounds. This causal agent appears to be of exceedingly small size, for diluted blood filtered through a Pasteur-

Chamberland B bougie can still cause the disease if inoculated intravenously into a non-immune.

It is obviously a living organism, and not a chemical substance, because of the time it takes to develop in man and the mosquito; for the incubation period in man is usually three days. The mosquito, in order to become infected, must bite a patient during the first three days of his illness, and then twelve days must elapse before the infected mosquito can transmit the disease.

The proof of the transmission of the disease by *Stegomyia calopus* was worked out by Reed, Carroll, Agramonte, and Lazear, by constructing a gnat-proof building divided into two gnat-proof compartments, into the first of which infected mosquitoes were liberated and allowed to bite a non-immune, while other non-immunes slept in the second compartment. The man in the first compartment developed an attack of yellow fever, while the others did not.

Non-immunes living in gnat-proof houses, with articles of clothing and bedding soiled with urine, fæces, black vomit, etc., from cases of yellow fever, did not contract the disease, though after this experiment was finished some were infected by means of the bites of infected mosquitoes, thus proving that they were not immune.

Marchoux and Simond extended this knowledge by showing that a *Stegomyia* can live for some thirty days, and lay seven batches of eggs. Those laid after the twelve days' incubation by an infected mosquito are also infected, and can transmit the contagium vivum to a second generation of mosquitoes, but these cannot infect non-immunes until fourteen days after hatching as imagines.

Further, the contagium vivum can apparently only exist in man and *Stegomyia calopus*, though it is true that a chimpanzee, after an incubation of three days, suffered from a typical attack of yellow fever, induced by experimental mosquito-bites, as was shown by Thomas in 1907. No other mosquito so far has been proved to carry the infection.

It appears, also, that the development in the mosquito depends to some extent upon the air temperature, as in the case of the malarial parasite.

The ætiology may therefore be summarized by saying that the causation is an animal parasite, living in the blood-stream of man and in the body of *Stegomyia calopus* Meigen, by the bites of which it can be transmitted to man and the chimpanzee.

Unfortunately, according to Theobald, it is necessary to change the old name *Stegomyia fasciata* Fabricius 1805 to *S. frater* Desvoidy 1827 or to *S. calopus* Meigen 1818, though there is some doubt as to whether the latter, which is, of course, the older term, really applies to the insect we know as *S. fasciata*. The reason for this change is because the term *fasciata* was used by Villiers in 1789 for a *Culex*.

Pathology.—In yellow fever the cells of the liver swell, and, pressing upon the bile capillaries, obstruct the flow of bile and cause a hepatogenous jaundice, characterized by yellow staining of the skin and tissues, and by the presence of bile in the urine. Further, the swelling blocks the intralobular capillaries, causing congestion of all the viscera drained by the portal vein, but especially of the pyloric end of the stomach and the duodenum, because of the arrangement of the veins from those parts. This stagnation of the blood may allow a secondary bacterial infection to take place, which shows its effect on the intestine and spleen.

The liver cells degenerate so extensively in bad cases as to cause the urea function to be considerably lessened in activity, and thereby a condition of ammoniæmia comes about, which produces most serious toxic effects upon the brain and other organs. In addition, the disease in some way seriously affects the endothelial lining of the blood capillaries, producing hæmorrhages in various parts of the body. If these leading features of the pathology are borne in mind, the post-mortem appearances and the symptomatology will be easily understood.

An attack generally confers a lasting immunity upon a person, and second attacks are rare, and it appears that the so-called racial immunity of people living in endemic regions is really an acquired immunity, due to mild attacks in childhood. Relative immunity can be acquired by inoculation of infected blood, heated to 55° C. for five minutes. Further, it is found that the serum of a convalescent has some protective power.

The Blood.—There is no marked alteration in the numbers or appearance of the erythrocytes, even in fatal cases. A few normoblasts are said to be present at times. On the other hand, there is a decided loss of hæmoglobin, though this is rarely below 90 per cent. in the first three or four days; and hæmoglobinæmia is said to occur in fatal cases before death. But this does not appear to coincide with the fall of specific gravity, which may be present without loss of hæmoglobin.

The leucocytes do not appear to be distinctly increased in numbers, varying from 3,200 to 20,000 per cubic millimetre, the increase, when present, being largely caused by polymorphonuclear leucocytes. The coagulation of the blood is diminished, and ammoniæmia is thought to be present in bad cases.

The Urine.—Albumin appears early—as a rule, on the second day—and increases in quantity remarkably, especially in severe cases. During convalescence it may disappear, or may last for months. Bile is present about the fifth or sixth day, and red blood cells may also occur, though leucocytes are rather rare. Casts are present—first hyaline, then granular, and finally epithelial. Urea is diminished in bad cases, and the diazo-reaction is believed to be absent in uncomplicated cases.

The Vomit.—The vomit is often distinguished as white, red, and black. The white is acid, colourless or bile-stained, and is composed largely of mucus. The red vomit contains bright blood, while the black is acid, containing hydrochloric acid, epithelial cells, red corpuscles, fat, débris, and micro-organisms, its colour being due to the presence of hæmoglobin, turned to acid hæmatin by the hydrochloric acid.

Morbid Anatomy.—The skin is yellow from bile-pigment, and blotched with post-mortem lividity and hæmorrhages. The liver is yellowish or brownish in colour, marked by hæmorrhages. The cells are swollen and in a state of advanced fatty degeneration. The gall-bladder contains inspissated bile, sometimes mixed with blood. The spleen is congested and soft. The stomach and intestines may be full of blood, and the mucosa of the stomach, especially that of pylorus and duodenum, is usually much swollen. The kidneys are, as a rule, normal in size, and not markedly congested. The cells of the tubules show fatty degeneration, and the lumen may contain granular débris. The bladder is usually empty. The heart shows ecchymoses, and effusions may be found in the pericardium. The lungs may be congested, and hæmorrhages may be found beneath the pleura. The meninges of the brain are congested, and hæmorrhagic spots may be seen.

Symptomatology.—An exact knowledge of the length of the incubation period is of the utmost importance from a prophylactic point of view. Calculated from experimental mosquito-bites, it varies from two days twenty-two hours to seven days five hours, but the latter figure was in a man who had had a mild attack. With regard to the former period, it is the shortest actual record, but some more doubtful figures, as low as two days one hour, are given. Excluding the man with the slight attack, the incubation period, as generally given by American observers, would be from two days twenty-two hours to six days two hours. Marchoux, Salimbeni and Simond consider that the incubation may be as long as twelve days, and draw this conclusion from inoculation of modified blood-serum, and also from natural infection. Carter's careful clinical records, however, give the incubation period as varying from three to five and three-quarter days.

The average time appears to be about five days, but to be on the safe side at least six to seven days must be allowed.

The fever is divisible into two paroxysms, separated by a remission or intermission. The first attack is characterized by headache, pale, then flushed, face, injected eyes, and pains in the body, and after the second day albuminuria; while the second attack shows the jaundice from which the disease obtains its name, and the hæmorrhages, of which black vomit and black motions form such ominous signs.

Prodromata are usually absent, but general malaise may be felt for some little time previously. The attack begins with a sensation of coldness, with or without rigors, and with severe frontal headache, pains in the back and limbs, while the face, at first pale, becomes flushed and painful, the skin congested, the eyes brilliant and injected, and photophobia is often present. The temperature rapidly rises to 103° F. or more; the respiration quickens and is laboured; the pulse is quick, full, and bounding, reaching to 100 or

120 per minute. The appetite is lost, and there is usually vomiting, associated with pain and tenderness in the region of the pylorus, and usually constipation. The urine is generally diminished, acid in reaction, with a high specific gravity, and albumin is present from the first or second day. Its passage may cause a sensation of burning. During this stage there is often insomnia.

On the second to fourth day the remission sets in, the temperature either dropping with a crisis, accompanied by sweating, to normal, or remitting to about 100° F., the flush and pains disappearing. In the former case the disease ends and convalescence begins. More usually, however, after a few hours' remission, during which the patient feels much better and sleeps well, the temperature again rises to 104° F. or 105° F.; but a most characteristic feature, called 'Faget's sign,' now shows itself, in that the pulse does not increase in rapidity as the temperature rises. On the contrary, as days go on, the pulse-rate tends to become slower and slower, without regard to the temperature. This sign depends upon the severity of the case, being most noticeable in severe types, in which it may be only 70 to 60 per minute, though associated with a high temperature.

During the second attack all the symptoms of the first paroxysm return, but the congestion of the skin is not so marked, and the yellow tint of jaundice appears for the first time, and deepens as the illness proceeds. The vomiting and tenderness in the stomach return, and are associated now with much thirst and prostration. The tongue is dry and furred, with red tip and edges. Hæmorrhages may now occur from the nose, mouth, or uterus, and the bad signs of black vomit and melæna may appear. The urine diminishes in quantity, and the albumin increases. In bad cases its excretion may totally cease. There is generally much restlessness, and often delirium.

Two courses are now possible. The first is that after three to four days' illness the temperature may decline, the urine increase in amount, the albumin diminish, and the vomiting gradually cease; while sweating may occur, and the patient, passing into a deep sleep, awakens on the road to convalescence. The second is that the temperature does not decline, the jaundice deepens, hæmorrhages appear under the skin, and from the regions indicated above hiccough, subsultus tendinum, clammy sweats, anuria, coma, and convulsions lead to death, which may, however, take place before the full development of these symptoms by cardiac or respiratory failure.

Varieties.—Three varieties may be recognized, though some authors describe more. These are the mild, the severe, and the malignant. The mild type consists of simply the first paroxysm, in which the temperature does not rise above 102° F., the urine contains albumin, and the fever ceases by crisis on the second or third day. The severe type shows the characters given above as typical for the disease. The malignant type begins with high fever, 105° F. to 107° F., with violent vomiting and the early appearance of black vomit and melæna, when the patient quickly becomes delirious, and dies in the initial fever.

Complications.—Any pre-existing pathological condition is serious in yellow fever, but renal and cardiac affections are perhaps the worst. Gangrene, abscesses, congestion of the lungs, and intussusception are possible complications arising in the course of the disease.

Sequelæ.—Boils and abscesses, dysentery and hepatitis, are the common sequels, but usually convalescence is not complicated or protracted.

Prognosis.—The mortality is very variously given, usually 10 to 25 per cent. for the United States and Europe, and 45 to 80 per cent. for the endemic area and West Africa. The extremes are 0·5 to 94·5 per cent.

All cases of yellow fever must be considered serious, especially if complicated with pre-existing disease, and constant care must be taken to measure the daily quantity of urine passed, and to estimate the amount of albumin; for marked diminution of the urine, especially anuria, is a grave sign. High temperatures, black vomit, melæna and other hæmorrhages, and marked disturbance of the nervous system, are all bad omens.

Diagnosis.—The typical symptoms in an epidemic will hardly be mistaken for any other disease, but the mild early case is very difficult to recognize. The best signs for a positive diagnosis are albuminuria, the epigastric tenderness, and, later, the jaundice, with Faget's sign, and the black vomit.

The most important diseases to differentiate in the first stage are dengue, subtertian malaria, blackwater fever, and relapsing fever. Dengue may be recognized by the absence of albuminuria, the preliminary rash, and leucopenia; subtertian malaria by the parasites in the blood, and the typical four-hourly temperature-chart, and the lack of albuminuria; blackwater fever by the hæmoglobin in the urine and the mononuclear increase; relapsing fever by the parasites in the blood, the leucocytosis, and the lack of albuminuria.

Treatment.—The modern treatment of yellow fever is based upon the work of Sternberg, Touartre, and Anderson.

As the cause of the disease is unknown, the treatment must aim at the prevention of the spread of the infection, the rapid elimination of the toxins, and the alleviation of the symptoms. To prevent the spread of the disease, the patient's bedroom must be rendered gnat-proof. The excretion of the toxins must take place by the bowels, skin, or kidneys, and therefore it is necessary to encourage the action of all three. The bowels are opened by a small dose of calomel, given more for the purpose of disinfecting the alimentary canal than for any other reason, followed by doses of sodium sulphate until the purgative action has been produced. After this the action of the bowels can be maintained by enemata of 1 tablespoonful of sodium sulphate dissolved in a pint of warm water, and given morning and night.

When there is severe headache, a hot mustard foot-bath may be given, which should relieve the head. After this the patient is warmly wrapped up in blankets, care being taken that he is not oppressed by the clothing, for only those who have been seriously ill can appreciate how embarrassing the weight of heavy blankets is to the heart. It is hoped that by these means the action of the skin will be stimulated.

In order to dilute the toxins, and at the same time to stimulate the action of the kidneys, an alkaline treatment, with plenty of fluid, is required. This can be effected by administering 2 to 4 quarts of iced effervescing Célestin Vichy water in the twenty-four hours, or the same quantity of any alkaline mineral water, to each pint of which 30 grains of sodium bicarbonate have been added; or Sternberg's celebrated mixture of—

Sodii bicarbonatis	gr. cl.
Hydrargyri perchloridi ..	gr. $\frac{1}{3}$.
Aquæ	ad ℥lx.

may be prescribed in 3-tablespoonful doses every hour; or an effervescing drink can be made up of sodium bicarbonate and fresh lime-juice, but care should be taken that this is mixed in such quantities as to be neutral, and it may, if necessary, be combined with sodium sulphate. If this alkaline treatment cannot be given by the mouth, then the bicarbonate of soda must be administered as warm enemata.

As regards symptoms, if there is great pain, this can be relieved by a small dose of phenacetin, while severe lumbar pain may be relieved by hot fomentations; but if no urine is passing, the warm mustard bath will be better.

Vomiting is treated by sips of iced Vichy, iced champagne, a blister to the pit of the stomach, a dose of a mixture containing chloroform, or a hypodermic injection of morphia. If there is much fever, this must be treated by cool sponging and cool applications to the head.

Black vomit should be treated by the application of the ice-bag to the pit of the stomach, and hæmorrhages in general should be met with doses of calcium chloride or hypodermic injections of adrenalin or ergotin.

In these bad cases it is advised by some authors to rub olive oil into the skin in quantity, with a view of ladening the endothelial cells of the blood capillaries with fatty particles, and so protecting them against the action of the toxins.

Anuria requires treatment by hot fomentations to the loins, or cupping and hot-air baths, and Carroll recommends the injection of 15 grains of urea, either hypodermically or by the rectum, with a view to stimulating renal activity, on the ground that in these bad cases the production of urea by the liver is not sufficient for that purpose.

Cardiac failure requires hypodermic injections of strychnine, camphor dissolved in ether or oil, or simply ether.

No food should be given for two or three days, but only the alkaline drinks, and champagne if necessary, the idea being to relieve the stomach and prevent the accumulation of waste products in the system, and so to save the kidney from too much work.

After this time, or if the temperature is below 102° F., milk and lime-water, toast-water, and barley-water may be given. With a view to saving tissue waste and getting fat into the circulation, pure frozen cream, cold white wine-jelly or lemon-jelly, should be given, or olive oil administered by the mouth or rubbed into the skin, as indicated above.

After the temperature has been normal for some three days, chicken-broth, custard-pudding, blanc-mange, etc., can be tried, and a few days later the diet can be gradually increased.

Strong beef extracts and strong alcoholic stimulants should be avoided, the best stimulant being iced champagne in tablespoonful doses.

Prophylaxis.—Yellow fever is generally conveyed from one place to another by ships, but in order to produce an epidemic several factors are necessary—viz., cases of the disease from which *Stegomyia calopus* may become infected, together with conditions of temperature, moisture, etc., suitable for the development of the germ in the mosquito, and also for the propagation of the mosquito itself, together with the presence of non-immune people for the mosquito to infect. It is also necessary to bear in mind that the incubation period is usually from three to six days, and therefore quarantine must be of at least five days, or, to be on the safe side, of six or seven days' duration. In order that the mosquito may become infected it must bite a patient during the first three days of the illness, and another twelve days must elapse before it is able to infect non-immunes. Therefore an infected ship must be anchored at least a quarter of a mile from the shore and from other ships. The sick must be placed in mosquito-proof rooms, the crew quarantined for at least six to seven days, and the whole ship disinfected by a Clayton's disinfector, preferably between 9 a.m. and 3 p.m., while the mosquitoes are quiescent. Dock-labourers working on suspected or disinfected ships should live in special gnat-proof buildings, and be under medical supervision.

With regard to an infected area, it must be remembered that *Stegomyia calopus* is essentially domestic in its habits, that it is active from 3 p.m. till early morning, but that it is quiescent between the hours of 9 a.m. and 3 p.m., when, therefore, visits can be made to infected areas without risk. Further, the mosquito is known to bite dead bodies and suck the blood, but this will seldom infect it, as a patient generally lives longer than the three days during which the disease can be communicated to the mosquito. Lastly, it can pass through a screen with fifteen meshes, but not through one with twenty meshes to the inch.

The mosquito does not die after laying its eggs, but lives until it has laid seven batches—*i.e.*, some thirty days. The eggs laid twelve days after infection are capable of carrying the infection into the second generation, which can spread the disease fourteen days after becoming imagines.

When a person is moved from an infected room, disinfection should be begun at once. All cracks, openings, etc., should be closed with paper, and fumigation carried out, preferably by means of sulphur dioxide gas, or if there is an objection to this because of the damage it causes, pyrethrum may be used, but must be burned in the proportion of 1 pound to 1,000 cubic feet of air-space if the mosquitoes are to be merely stupefied, and 2 pounds if they are to be killed; or tobacco, 1 pound per 1,000 cubic feet, may be used.

In addition, if an epidemic is to be eradicated, cases must be at once notified to the central authority, and patients must be strictly treated in mosquito-proof rooms, and every person, immune or non-immune, must use mosquito-curtains, while an anti-mosquito scheme on the lines mentioned under Malaria must be undertaken. Special care must, however, be taken to eradicate, after a careful survey, all the breeding-places, not forgetting those in old tins, cocoanut-shells, gutters, small pools, etc. In endemic areas houses and public buildings should be rendered gnat-proof. Lastly, when an epidemic breaks out in any place, it may be taken for granted that the importation took place at least two to three weeks prior to the discovery, for this is the time required for the incubation of the germ in the mosquito and in man; and it may also be assumed that mild cases are probably being treated for influenza or malaria. Therefore a house-to-house visitation is almost necessary, in order to find out the extent of the outbreak.

Given a free hand and plenty of money, there should be no difficulty in dealing with a threatened epidemic, but the public must be won over to assist, and offenders must be fined for transgressions against sanitation, as is done by the Americans in Panama, the offences being the presence of mosquito larvæ, imperfect screening of the house, accumulation of water, etc.

No anxiety need now be felt as to the spread of yellow fever to Asia when the Panama Canal is open, for it appears as though not merely yellow fever, but all infectious and contagious fevers, are bound to be eradicated from the Canal zone under the able American rule.

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CHAPTER XXXI

UNDULANT FEVER

Synonyms — Definition — History — Climatology — Ætiology — Pathology — Symptomatology — Diagnosis — Prognosis — Treatment — Prophylaxis—References.

Synonyms. — Mediterranean Fever, Malta Fever, Bruce's Septicæmia, Gibraltar Fever, Neapolitan Fever, Cyprus Fever, Febris Undulans, Febris Sudoralis.

Definition.—Undulant fever is a chronic, rarely an acute, febrile disorder, with many undulatory relapses, caused by *Micrococcus melitensis* Bruce, and usually spread by the agency of goat's milk.

History.—Undulant fever has probably existed in the neighbourhood of the Mediterranean for centuries, and passages are cited from Hippocrates recounting cases of long-drawn-out fevers, with short apyrexial intervals lasting as long as 120 days, which may perhaps refer to the disease.

In the eighteenth and the early part of the nineteenth centuries references were made to protracted fevers occurring in Malta by various observers—*e.g.*, Howard in 1786, Hennen in 1816-25, Davy in 1842-62—but it is difficult to be certain what disease is referred to. During the Crimean War there appears to have been a very large temporary increase of the fever incidence in Malta, much of which was undoubtedly enteric, but some of it was not. The change in the type of fever appears to have been so marked that some people thought that a new disease had been imported from the Crimea by the returning troops.

In 1859 Marston, having personally suffered from the fever, first gave an accurate account of its clinical history and post-mortem appearances under the term ' Mediterranean remittent ' or ' gastric remittent fever,' distinguishing it clearly from enteric and what he called ' Maltese fever.'

From this date there seems to have been much confusion, for it was often diagnosed as some form of rheumatism, but the disease appears to have been clearly recognized by Boileau, Chartres, Thomas, and others. In 1879 Veale gave an account of it as seen in invalids at Netley, as did Fazio in Naples, who not merely described the disease, but suggested that it might be found to be of bacterial origin.

In 1886 it was proved to be a separate pathological entity by Bruce, who discovered a micrococcus in the spleen. In 1887 he found the organism several times, and was able to cultivate it on agar-agar, and to reproduce the disease by inoculation in monkeys, from which he again obtained the organism in pure culture. In 1889 he published the first full account of the clinical symptoms, and in 1891 he grew the micrococcus from blood aspirated from the spleen during life. Thus, Bruce proved that this organism, which he called *Micrococcus melitensis*, was the true cause of the fever.

In 1897 Wright and Semple showed that the disease could be diagnosed by the agglutination of the micro-organism by the serum of patients, and in the same year Hughes published a full historical and clinical account.

In 1904 a Commission was appointed by the Admiralty, the War Office, and the Civil Government of Malta to investigate the disease. This Commission demonstrated that the micrococcus leaves the body mainly in the urine, and is then capable of existing for a long period outside the body. It was also found by Zammit and others in goats, which it does not appear to affect injuriously, living in the blood-stream, and also occurring in the milk, by means of which the disease is conveyed to man.

Prophylaxis on the lines indicated by the ætiology has resulted in the reduction of the disease in Malta from 643 cases in 1905 to 7 cases in 1907. In 1906 Lamb and Pai proved that the organism existed in India in men, while Foster did the same for goats.

Climatology.—The endemic areas of the disease are undoubtedly, firstly, the coasts and islands of the Mediterranean, and, secondly, India, especially the Punjaub, where the causative organism has been obtained in human beings and goats. We have met with cases in Ceylon. Recently it has been reported from many other parts of the world on the strength, in many cases, of the serum diagnosis, which, however, is by no means infallible.

It is certainly a disease of tropical and subtropical climates, and exists, in addition to the two localities mentioned, in East and South Africa, China, the Philippine and Fiji Islands, North and South America, and the West Indies. It occurs all through the year, but is more common in the warm weather in Malta.

Ætiology.—The cause, as has been indicated in the history, is *Micrococcus melitensis*, which is found in the spleen, liver, kidney, lymphatic and salivary glands, the blood, bile, fæces (once only), and probably in the alimentary canal (as Eyre's researches on rabbits indicate), the urine, and the milk. It does not occur in the expired air, the sweat, the saliva, or in scrapings from the skin.

It can be inoculated, and it may be found in the stomach of mosquitoes which have fed upon patients, but neither they nor any other biting fly, such as a *Stomoxys*, or a flea, have been proved capable of spreading the disease. It is, however, very resistant, and can live for eighty days in dust, or in water, fresh or salt, for a month, but has never yet been found naturally in air, dust, soil, or water, neither have any of these in a natural way been proved capable of spreading the disease. It is, however, true that dust, infected with damp organisms from a culture, has infected monkeys, as have suspensions of the organism when applied to mucosæ of the nose or throat. It appears, however, to be best conveyed to animals in food, especially milk.

The organism has also been found by the serum reaction to be present in 50 per cent. of the goats examined in Malta, and has also been obtained from the milk of 10 per cent. of the goats investigated, and, when looked for, it has been found in the blood of goats and other animals. Notwithstanding this infection, the animals are quite healthy. It appears to be conveyed to man by infected milk; the best evidence in favour of which is the infection of a ship's crew by the milk of goats, which were being conveyed from Malta to America, 53 per cent. of which were found to be infected.

The distribution of the disease, therefore, depends upon the consumption of infected goat's milk, for people who use this milk will be more liable to infection than others—hence its occurrence in Malta and the Mediterranean districts, in South Africa and India. This is also the reason why the richer classes are more affected than the poorer, and why individual institutions are picked out. It also explains why there is no age or sex incidence, why infants rarely suffer, and why occupation and surroundings have but little influence. The micro-organism has been also found in dogs, mules, and other animals, in Malta.

Pathology.—The micrococcus enters the blood-stream via the mucosæ of the alimentary canal, and causes a genuine septicæmia, with enlargement and congestion of the spleen as the most marked feature; so that the disease somewhat resembles typhoid fever in many of its characters, without, however, producing such typical intestinal lesions as that disease. According to some authors (Ross, etc.), the germ can be conveyed by mosquitoes, but this is far from being proved. For clinical and experimental reasons Bruce believes that one attack produces an immunity, but Manson and Bassett-Smith doubt this.

Morbid Anatomy.—The morbid anatomy shows an enlarged and congested spleen, some congestion of the liver, kidney, and mesenteric glands, duodenum, jejunum, large intestine, and lungs. The spleen is usually much enlarged, weighing from 10 to 44 ounces. It is dark red in colour, and may be soft and friable, and is very congested, with enlarged Malpighian bodies. The liver is congested and enlarged, and shows cloudy swelling, with a round-celled infiltration between the lobules. The kidney is congested, and may show a glomerular nephritis. The alimentary canal may not merely be congested, but the colon may also be ulcerated, particularly in cases of hæmorrhage. The lungs are congested, especially at the bases, and may show patches of consolidation.

Symptomatology.—Monkeys fed with infected milk require an incubation of fifteen days, while in human beings the period, according to Johnstone, is fourteen days.

The prodromata are usually malaise, chilliness, headache, muscular pains, and dyspepsia. The onset comes on gradually, and the patient continues his work though feeling ill, while the temperature rises in a ladder, being higher each evening, and remitting somewhat in the morning. About the fourth or fifth day of the illness a doctor is consulted for the headache, and pains in the body and limbs, which may have been thought to be rheumatic. The patient looks ill, and his temperature is found to be about 103° F., his pulse 80 to 90, and his tongue coated dorsally with a white fur, while the edges are red, and may be indented by the teeth. There is usually a slight sore throat and a tender epigastrium, with some bronchial catarrh or congestion of the lungs, and enlargement and tenderness of the spleen, which develop in the course of a week or so.

All these symptoms continue for about a couple of weeks, the temperature remaining high—103° F. to 105° F.—but at the end of this period the fever declines, and the temperature may become normal, while the patient feels much better. In a day or so, however, a relapse occurs with much the same symptoms as the attack. This relapse subsides, and another follows, relapses and intermissions recurring for months.

The temperature now becomes undulating, with a marked rise at night and fall in the morning, while the patient becomes more and more anæmic, weak, and wasted. The alimentary canal is irritated, as is shown by the dyspepsia and the constipation or diarrhœa. The throat may be sore, the gums spongy, and bleed on pressure; the spleen is often enlarged and painful, and the lungs may show signs of bronchitis, and occasionally lobular pneumonia, while the heart is easily excited, and hæmic murmurs are heard. The patient shows signs of prostration and headache, and pains all over the body are felt. Insomnia and hysterical emotions are not uncommon, but actual delirium is not usual, and the memory may be impaired, while neuritis—*e.g.*, sciatica—may occur. The skin is pale but damp, due to local or general perspiration, which is very common, and occurs with each remission of the temperature, the sweat being of a peculiar disagreeable odour. Sudamina are not uncommon after the third week. Desquamation may occur, as well as prickly heat, boils, bed-sores, subcutaneous abscesses or hæmorrhages.

The joints may become swollen and very painful, but the skin over them is seldom reddened. Of all the joints the hip, shoulder, ankle, and knee appear most commonly affected. Inflammation or neuralgia of the testes may occur, and at times the parotid also becomes inflamed.

The blood has been more particularly studied by Bassett-Smith and Gabbi, who find a secondary anæmia with a loss of 20 to 40 per cent. of the corpuscles, with some poikilocytosis and an even greater reduction of the hæmoglobin. The leucocytic count is normal, but there is a decrease in the polymorphonuclears, and an increase in the mononuclears to 26 to 76 per cent. Phagocytosis is said to be diminished, as is also the bactericidal power of the blood.

Agglutination is a useful test, but must be in a dilution of at least 1 in 50, otherwise errors in diagnosis will result. Bassett-Smith recommends 1 in 50, with a time-limit of thirty minutes. This reaction is said to last for a very long time—*i.e.*, two to seven years. Birt and Lamb have made this serum reaction the basis of prognosis, which is considered to be unfavourable if continuously low, or rapidly altering from a high to a low figure. Agglutinins are present also in the saliva (saliva-reaction of Polacci and others).

The urine is passed in fair quantity, and has a slightly acid reaction, with a deposit of urates and phosphates, but there is very seldom any albumin, though bile may be present in severe cases, and the specific germ can be found in the urine even two years after an attack.

The patient is now anæmic, and prostrated by the repeated attacks of fever, when gradually the symptoms begin to improve, the intermissions lengthen, the attacks lessen in length and severity, the temperature becomes normal or subnormal in the morning, rising a little at night. Gradually this evening rise diminishes until it stops, the tongue clears, the symptoms abate, and convalescence begins after an illness of from 20 to 300 days, with an average of 90 days.

Varieties.—Two varieties distinct from the typical description given above are recognized by Hughes—viz., a malignant and an intermittent—to which a third or ambulatory variety may be added.

The Malignant Variety.—Suddenly, without warning, the patient is attacked with high fever, the temperature rising to 104° F. or 105° F., with severe pains all over the body, flushed face, and all the other symptoms already mentioned, but in an aggravated form, and often associated with basal pneumonia, and diarrhœa with offensive stools.

After a little the symptoms abate somewhat, but instead of improving, the pulse becomes intermittent, the breathing is laboured, and vomiting becomes serious, and the patient gradually passes into the typhoid state, when hyperpyrexia sets in, and death takes place from the fifth to the twenty-first day of the illness.

The Intermittent Variety.—The onset in this variety is very gradual. When the attack is fully developed, the temperature is about normal in the morning, but rises in the afternoon to 99° F. or 105° F., this rise being accompanied by malaise, irritability, and chilliness. During the night sweating occurs, and the temperature falls to nearly normal. This fever continues usually for about six weeks, but may be prolonged for about six months, and is usually unassociated with any serious symptoms—in fact, so mild may the attack be that it is not discovered until the patient's general health begins to be unsatisfactory, and he seeks medical advice.

The Ambulatory Variety.—Apparently at times the organism may produce such little effect that the infected person may be unaware that he is suffering from any complaint, and may pursue his daily vocation. Thus, out of 525 dock-hands examined by Shaw at Malta for the serum reaction, 79 gave positive results; and of 22 tested, 9 contained the organism either in the blood or urine, or both.

Complications.—Ulcers may occur in the small and large intestine, and give rise to hæmorrhage, while persistent vomiting, diarrhœa, hyperpyrexia, pneumonia, pleuritic effusion, and cardiac failure all form serious complications. Orchitis is common.

Sequelæ.—Paralysis, wasting of muscles, loss of memory, tremulousness, and neurasthenia are possible sequelæ.

Diagnosis.—The principal clinical signs on which to base a diagnosis are the undulant character of the fever and the articular symptoms.

Bacteriological methods of diagnosis should be always resorted to whenever possible. The agglutination test, if properly performed, is, in our experience, sufficiently reliable, but in any doubtful case the blood should be investigated for the presence of *Micrococcus melitensis,* using nutrose media or the dilution method. In case of a negative result, the examination should be repeated at least three times at different periods of the disease.

The diseases from which Malta fever must be distinguished are typhoid, recognized by a positive Widal reaction, malaria, recognized by the presence of the blood parasites, and kala-azar, by its parasite.

Prognosis.—The prognosis in the usual form and the mild type is good, the dangers being syncope and complications. The sudden malignant type is rare, but very fatal. The mortality is placed as low as 2 per cent. by Bruce, but others have reckoned it as high as 13 per cent. for the army in Malta, and 9 per cent. for the civilian population.

Treatment.—The treatment is entirely symptomatic, as no drug is known which will kill the parasite, and the opsonin treatment has not been successful. The principal symptoms which require treatment are fever, pain, gastric and intestinal disturbances, congestion of the mouth and throat, nervous symptoms, and hæmorrhages. Attention must be paid to the skin, lungs, and heart.

The patient also requires the utmost care as regards nursing, and in the acute stages the bed-pan should be used. Chills must be avoided by the use of warm clothing, and the room should be rendered gnat-proof to keep off flies. Care must be taken that the bladder is emptied regularly.

The fever is best treated by tepid sponging when moderate, and cold sponging and ice-packs when severe. As regards pains, headache is treated by bromides, with or without morphia, or small doses of phenazone or phenacetin with caffeine may be used; pains in the joints by hot fomentations with belladonna or opium; general pains by a hypodermic injection of morphia. Scott's dressing may be applied to a swollen and painful joint, and pain in the soles of the feet may be treated by cold-water applications. Vomiting is to be treated as described under Malaria. Constipation is met by a dose of calomel and a saline, and the bowels kept open by compound liquorice powder or enemata. Diarrhœa is controlled by some ordinary astringent mixture, or bismuth, or tannalbin powders in some form, while Dover's powder is very useful, for it also relieves pain.

If the colon is affected, the treatment may be on the same lines as for a mild attack of dysentery, boracic enemata being used. Small doses of calomel—$\frac{1}{6}$ grain—three or four times a day as an intestinal disinfectant are useful. The dyspepsia may require treatment on the ordinary lines. A mouth-wash of glycothymoline, or glycerin borax and myrrh, or listerine should be used, and the throat cleaned by an alkaline spray, and then astringed by a gargle. The nervous symptoms are soothed by cool sponging, or by the bromide and morphia mentioned above. Hæmorrhages must be controlled by rest, applications of ice, careful regulation of food, and administration of adrenalin and calcium chloride. The skin must be carefully watched, and prickly heat, boils, or threatening bedsores promptly treated, and special care must be taken that after sweating, which often occurs at night, the clothes are changed. The lungs should be watched for signs of congestion and pneumonia or pleurisy, which must receive the usual treatment. The heart must be carefully studied, and digitalis, strychnine, iron, or some other cardiac tonic administered as required.

Low diet is necessary during the attack; but if milk is used, care must be taken that it is not goat's milk, or derived from an infected source, otherwise, while treating the patient, a process of reinfection may also be carried out. During the intermission the patient should be given light nutritious food, care being taken to see that it is really digested.

Stimulants, in the form of champagne or brandy, are often necessary in severe cases, because of the cardiac and general depression.

De Brum claims to have had good results in the treatment of Malta fever by giving massive doses of quinine (1 drachm daily).

Prophylaxis.—The prophylaxis appears to be simple and to be summarized, consists in the avoidance of goat's milk, but, of course, it has not yet definitely been proved that this is the sole method of infection. The Gibraltar authorities have completely stamped out Malta fever by prohibiting the importation of goats from Malta, which, together with the diminution of the disease in Malta, clearly demonstrates the great practical value of the work performed by the late Commission.

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CHAPTER XXXII

PLAGUE

Synonyms — Definition — History — Climatology — Ætiology — Pathology — Symptomatology — Diagnosis — Prognosis — Treatment—Prophylaxis—References.

Synonyms.— Black Death, Pestis, Lues, La Peste (French), Die Peste (German), Peste Bubbonica (Italian), Mahamari (India), Yeki (Japan), Kota-wen (China), Kaumpuli (Uganda).

Definition.—Plague is a septicæmia caused by the *Bacillus pestis*, which produces an epizootic in rats, from which it spreads to man and other animals by the agency of fleas.

In man it causes an acute specific fever, characterized by an inflammation of the lymphatic glands ; a secondary septicæmia, with hæmorrhages, skin necrosis, and often a secondary pneumonia ; or it may give rise to a primary pneumonia or a primary septicæmia. The pneumonic forms are highly infectious, spreading from man to man by aerial convection.

History and Epidemiology.—Plague, because of its epidemicity and its high mortality, is much feared, and has been noticed from early times to be associated with a mortality among rats. Thus, the Bible contains an account of an epidemic disease in the Philistine country which produced buboes in human beings and killed rats (' mice of the field '), and there is also reference in Simpson's work on plague to the fact that Sennacherib's army was attacked by a pestilence in which field-mice were in some way concerned.

But it was not until the outbreak in Pelusium, a great Egyptian market, in A.D. 542, that the disease was seriously considered, for it spread to Byzantium, at that time the city of the world, and then passed into Asia, and through North Africa into Western Europe as far as Ireland, lasting in epidemic form for about 200 years.

The next outbreak is in the eleventh century, when it spread as a pandemic, reaching a maximum in the fourteenth century, and gradually declining, until suddenly, in the seventeenth century, it left Western Europe, and in 1884 it vanished from Eastern Europe, and practically from Asia Minor, remaining, however, in the district of Assyr, in West Arabia.

This great pandemic stirred Governments to take prophylactic measures, and Count Bernabo, of Reggio, is found impressing stern quarantine laws in 1374, while the Venetians, in 1403 and subsequent years, laid the foundations of modern prophylaxis by erecting the first lazaretto, or depot for the isolation of the sick, by instituting the quarantine for forty days (hence the term), and by the disinfection of clothing and merchandise. Further, they compelled the ship coming from an infected port to hoist a yellow flag, and to allow an inspection of the crew and passengers before it was given pratique.

In the meanwhile plague occurred in India, where the first records are to be found in a sacred Hindu book, the 'Bhâgavat Purana,' believed to be 800 years old, which describes a disease in man associated with death among rats, and advises the vacation of a house in which dead rats are found. Plague is known to have formed epidemics in the eleventh, twelfth, fourteenth, fifteenth, sixteenth, and seventeenth centuries, after which, apparently, it disappeared only to reappear in Gujurat and Sindh in 1812. In 1823 it was discovered that plague existed in the districts of Garhival and Kumaon, but no one has been able to determine from whence it came, or how long it had existed in those places. It is now said to be endemic there, and to form the focus for the epidemic of Delhi in 1825, and Rohilcund in 1836. In 1836 plague broke out in Rajputana—the so-called Pali Plague, from the place first infected—and lasted two years. Since then plague has been introduced into India from China, and has spread therein, as will be explained later. With regard to China, it is difficult to obtain any exact information, but it is possible that plague may have been introduced at some time by Mohammedans returning from Mecca via Burmah to the province of Yunnan, where, according to Minakata, it was known some time between 1736 and 1809, for a Chinese author who lived during this period gives an account of a disease which caused death in men and rats. From that time plague has been endemic in Yunnan, from which it appears to have spread southwards, reaching Pakhoi, on the southern coast, about 1867, where it disappears and reappears at intervals without apparently affecting other regions, until 1894, when, after an absence of ten years, it again reappears, and, infecting the district of Kaochao, spreads via Canton to Hong-Kong. In June, 1894, Kitasato found the causative bacillus in cases in Hong-Kong, and this was confirmed by the independent discovery of the same bacillus a little later by Yersin in the same town. In 1896 it spread from China to Bombay, from which it has gradually extended over the larger portion of India, causing an enormous number of deaths.

In 1897 a most important international conference was held at Venice, when protective measures were agreed to, and regulations framed to combat the disease, based upon the view that the sick person and his personal effects were the chief source of danger, and a quarantine of ten days from the last infected port was placed upon healthy ships. In 1898 the pandemic spread from India to Madagascar, and from there to Lorenzo Marquez and Mauritius. In 1899 it affected the Malay States, the Philippine Islands, New Caledonia, the Sandwich Islands, Australia, San Francisco, New York, Asuncion, Rosario, Buenos Ayres, Rio de Janeiro, Oporto, Lisbon, and Alexandria. In 1900 it passed from Rosario to Cape Town, and also appeared in Glasgow.

In 1903 a Second International Conference was held in Paris, which issued a series of regulations confirming those of the Venetian Conference, except that the quarantine of ships was reduced to five days, and that the agency of the rat in the disease was clearly recognized, and regulations for its destruction framed. Further, this Conference established an International Sanitary Office in Paris for the purpose of collecting and transmitting sanitary information to the different countries. In 1904 Johannesburg was attacked, in 1905 Persia and Russia, in 1906 Leith, and in 1907 Accra, on the Gold Coast, in which year the disease was widespread throughout the world, occurring in India, Persia, Arabia, Egypt, Tunisia, Algeria, West Africa, South Africa, East Africa, Russia, Glasgow, Argentina, Brazil, Chili, Paraguay, Peru, Uruguay, United States, Australia, New Zealand, Japan, China, and Indo-China.

Turning to Africa, which has already been mentioned to have been often infected, it is now known to possess two infected endemic areas—viz., Benghazi, in Tripoli, and Buddu, Koki, and Nkole, in Uganda, from the latter of which an epidemic is supposed to have spread into the Kissiba district of German East Africa.

Such a pandemic as the one just described could hardly exist without numerous careful inquiries into its causation and prevention, for Governments were interested in its prevention. Therefore Austrian, German, and Russian Commissions were appointed, and did excellent work. In 1898 the first

Plague Commission of India was appointed, and was followed by an Advisory Committee of the India Office, Royal Society, and Lister Institute, appointed in 1904, and, finally, in conjunction with this Committee, the Second India Commission was appointed in 1907, and has done excellent work in tracing the ætiology to the rat-flea.

In the meanwhile individual observers had also studied the disease—*e.g.*, Lustig of Florence, and Haffkine of India, had brought forward protective vaccines, while Verybitski, of St. Petersburg, showed, in 1904, the importance of the flea as a cause of the disease.

Climatology.—At the present moment the so-called endemic regions are an area in the Kurdistan Hills, with a secondary area in Irak, in Mesopotamia; another area about the Himalayas—*i.e.*, Kumaon and Gurwhal, in India, Thibet and Yunnan, in China—and four lesser areas—viz., Benghazi, in Tripoli, Uganda, in Central Africa, Azeer, in Arabia, and the trans-Baikal Province of Siberia—but only the first two are of real importance as far as we know. On the strength of these two different regions an attempt has been made to differentiate two distinct types of the disease: the first, the Western Asiatic, being mild, and pneumonic cases rare, while it is often self-limited, not capable of wide distribution, and not associated with an epizootic in rats; the second is the Indo-Chinese plague, or the disease, as it is known to-day. It seems, however, hardly likely that such a distinction will be supported when the disease in the first area is carefully studied. Climate appears to have but little influence on the distribution of the disease, and soil apparently none. The hot season of the tropics and the winter season of the Temperate Zone are deleterious to the spread of the disease. The reason for this appears to be the effect of temperature on the bacilli in the flea, which disappear rapidly from its stomach above 85° F., and are very ineffectual at that temperature, while at 70° F. they are virulent. Moreover, as has already been stated in the chapter on Fleas, high temperatures restrain the adults from laying eggs and the larvæ from developing.

When temperatures below 50° F. are reached, it is found that rats die before the bacilli pass into the blood, and therefore the fleas do not become infected when sucking the blood. A temperature of 70° F. is therefore best for the propagation of an epidemic.

Ætiology.—The ætiology of plague has been placed on a sure footing by the labours of Kitasato, Yersin, Thompson, Ogata, Kolle, Martini, and the Special Committee already mentioned, together with the Second Indian Commission.

It is caused by the *Bacillus pestis* of Kitasato and Yersin, which is found in the fluid of the initial cutaneous vesicle, the buboes, the spleen, the blood, and the sputum in cases of pneumonia. When inoculated into monkeys, cats, rats, guinea-pigs, squirrels, monbooses, bats, jerboas, etc., it causes the typical disease, while in govines and equines it only causes local reactions. Canines, birds, and reptiles appear to be immune. It causes a natural epizoötic in rats, which apparently is the true disease, from which that of man must be looked upon as an offshoot. In rats it produces either an acute or a chronic attack, the post-mortem appearances of which are different.

In the acute type a bubo is found in 85 per cent. of infected rats, being present usually in the neck or axilla. If the bubo is absent, a plague rat can be recognized by the subcutaneous congestion, the purplish-red appearance of the muscles, the waxy, mottled, or finely granular appearance of the liver, the hæmorrhages, and the pleural effusions. The diagnosis can be confirmed by finding the bacilli in the bubo, the spleen, or the blood.

The chronic type of the disease consists of encapsuled caseous foci, or abscesses containing bacilli, and found in the spleen and other organs. This form plays no part in the spread of the disease.

The epizoötic does not continue with equal virulence all the year round, for it appears to be profoundly altered by the temperature being diminished in the hot weather of the tropics and the cold weather of the Temperate Zone. Thus in Bombay the Plague Commission found 1,766 plague-infected rats in one week in the season December to May, and only 20 to 30 in the season June to November. The cause of this variation has already been given.

But all rats are not equally infected, for it was found in Bombay that there were two principal species, *Mus norvegicus* and *M. rattus*, and that during the epizoötic period no less than 1,334 of the 1,766 belonged to the former species, while in the non-epizoötic period it alone carried on the disease. The reason assigned for this difference was that the numbers of the flea population of the two rats were very different, *M. norvegicus* possessing about double the number of *M. rattus*. Further, it was noticed that the curve of *M. norvegicus* infection began to rise about ten days before that of *M. rattus*, which points to the origin of the infection of the latter from the former in the first instance.

M. norvegicus, which is not nearly so numerous in Bombay as *M. rattus*, lives outside houses, for the most part in sewers, drains, and stables, and has a great facility for burrowing, and is a good climber. It, however, has never been found above the third floor of a house. It forms its nest in one of its burrows, and breeds all the year round, but has two special seasons, one in March, and one from June to October, the average family being eight.

Mus rattus is more common in Bombay than *M. norvegicus*, especially in houses, where it increases relatively to the other up to the third floor, but above that level it alone infects the house. It is not so common in gullies, compounds, stables, go-downs, and food and tea shops as *M. norvegicus*. The common meeting-ground of the two species appears to be the lower floors of houses, gullies, and go-downs. Though a domesticated rat, it can climb and burrow. It forms its nest in cupboards, heaps of firewood, etc., and breeds all the year round, but especially from June to October, the average family being five.

The spread of the plague from *M. norvegicus* to *M. rattus*, according to the experiments of the Commission, is neither by direct contact, nor by air, soil, or food, but solely by the flea. Contact was excluded by placing healthy rats in the same room with plague-infected animals from which the fleas had been removed, when it was found that none of them developed plague. The experiment was kept up for a long time, replacing dead infected rats with freshly infected rats, and, further, the room was never cleaned out, so that the healthy animals lived in contact with the infected urine and fæces, and even ate food polluted therewith, and yet not one contracted plague, thus excluding transmission by contact, soil, and food.

Again, when healthy animals were suspended in cages 2 feet from the ground, so that the fleas could not get to them, or placed on the ground, and surrounded by 6 inches of tangle-foot, over which a flea cannot pass, as it is said to be incapable of jumping more than 4 inches, or surrounded by a curtain of wire gauze so fine that a flea could not penetrate it, and exposed to infection, they escaped, though others not so protected became infected, thus disproving aerial infection. Further, the transmission by the rat-flea was proved by constructing a glass box, inside which two wire cages were placed at a little distance, but side by side, each standing in a tray filled with sand. Each cage had a lid, through which rats, food, water, etc., could be introduced, and the whole apparatus was covered in with fine muslin to prevent the escape of the fleas. A plague-infected rat and a number of rat-fleas were placed in one cage. When this rat died, a healthy rat was placed in the other cage, and after some time the dead body of the infected rat was removed, when it was found that the new rat became infected with plague, and fleas containing plague bacilli were found upon it. This experiment was repeated many times, 45 per cent. of the exposed rats taking the disease. Further, fleas infected by biting plague rats when placed upon healthy rats produced the disease in 55 per cent. of the experiments.

The Commission calculated that the blood of an ordinary plague-rat in two-thirds of the cases contain more than 100,000,000 bacilli per cubic centimetre, and that a flea's stomach could hold 0·5 cubic millimetre of blood. Therefore when the flea gorged itself on the average plague-stricken rat it received at least 5,000 bacilli. These bacilli are found only in the stomach and in the alimentary canal posterior to that viscus, especially the rectum, and escape from the flea solely with the fæces. It was proved, however, that the bacilli multiplied in the body of the flea by allowing infected fleas to feed solely on uninfected rats, a fresh one being supplied each day, when abundant bacilli were found up to the twelfth, and once to the twentieth day, thus proving that multiplication must have taken place, otherwise the original number of bacilli would have become much diluted by the feeds with fresh blood. Further, it was discovered that the proportion of fleas in whose stomach multiplication took place was six times greater in the epidemic than in the non-epidemic season. In the former season the bacilli could be found easily up to the fourth and even to the twelfth day, while in the latter never after the seventh day. Infected fleas were found to transmit the disease for seven to fifteen days.

The method of infection probably is in one of two ways, either fæcal pollution of the proboscis, or else fæcal pollution of the wound made by the proboscis, which was found quite large enough for the purpose of introducing the bacilli into the skin. Both males and females can transmit the disease, but it was found that one infected flea alone was unlikely to do so. The flea most commonly found on rats, and the one by which the infection in these experiments was usually spread, was *Leomopsylla cheopis*, but others—*e.g.*, *Ceratophyllus fasciatus* and *Pulex irritans*—were found also capable of causing the disease.

With regard to the spread of the disease to man, the Commission believes that the infection generally comes from *Mus rattus*, because the habits of that rodent bring it into close relationship with man, and because the curve of its epizoötic begins to rise ten to fourteen days before that of the epidemic. This period is calculated to be made up of three days, during which the flea leaves the dead rat, to which is added another three days, which is the incubation period of plague in man, and five and a half days, which is the average duration of the fatal illness in man.

Leomopsylla cheopis appears to be the flea by which plague is spread from *Mus rattus* to man. This rat-flea will not merely bite man when it cannot get rat's blood, but is capable of living for three to four weeks on man's blood, and is often found on human beings after inspection of plague-stricken houses.

Further, it is believed that the spread of plague is due, not to migration of rats, but to the carriage of infected rats on ships, and of fleas in merchandise or on human beings. The Commission apparently consider the last to be the most important method.

Pneumonic plague, which occurs only in 2·5 per cent. of cases, does spread from man to man by bacilli carried by the air, but the bubonic or septicæmic is not spread from man to man, but from rats to man. The epizoötic is the real disease, and the epidemic is only an offshoot.

The above ætiology explains fully the predisposing causes of sex, women staying more in the house than men ; of house, of season, of climate, and also the carriage of the disease from one place to another by people, fodder, grain, bales of cotton and clothing, rags, etc.

Pathology.—Plague is a hæmorrhagic septicæmia in the rat, which is communicated to the human being by flea-bites. The site of inoculation is sometimes marked by a vesicle, the contents of which contain the *Bacillus pestis* in considerable numbers. The bacilli then travel via the lymphatics to the nearest lymphatic glands, which they may traverse, and, passing through the thoracic duct, enter the blood-stream, and cause a septicæmia. More usually they remain and grow in the peripheral lymph sinus of those glands in which they or their toxins cause degenerations of the cells, periglandular serous infiltration, and, later, degeneration of the walls of the bloodvessels and hæmorrhage. The lymphatic glands are matted together by the exudation from the primary bubo. The glands usually affected are the femoral, inguinal, axillary, iliac, or cervical, which may briefly be classified into the groin, the axillary, and cervical glands.

The recent Indian Commission points out that the reason why the groin glands are so frequently attacked is simply because they drain the largest skin area, for they say that the areas drained by the glands of the neck, axilla, and groin are in the proportions of 1 : 1·8 : 5, while the number of cervical, axillary, and inguinal buboes are in the proportions of 1 : 1·3 : 5·8, and that therefore there is no seat of election as to where the plague bacillus enters.

From the primary bubo the bacilli may travel along the lymphatics to the next chain of glands, in which they produce the secondary bubo, and from this they may enter the blood-stream via the lymphatics. The bacilli, however, may gain direct access to the blood-stream through the injuries to the walls of the veins in the primary bubo. Once the blood-stream is reached the disease becomes a septicæmia, and affects the lymphatic glands, forming tertiary buboes; the lungs, causing bronchitis and secondary pneumonia; the spleen, liver, kidneys, skin, and other organs; and, finally, leaves the body through the kidneys, skin, and mucosæ, escaping in the urine, fæces, and sputum (if there is pneumonia), as well as by any discharges or hæmorrhages from the skin. The excretion, via the sputum and saliva, can proceed for a period of at least forty-eight days after the temperature is normal. Further, as in chronic plague in rats, the bacilli may be found in abscesses some two and a half months after an attack. The chemical pathology of the disease is not well known.

Morbid Anatomy.—The characteristic features of a plague post-mortem are the hæmorrhages and the buboes, which have recently been studied in detail by Dürck. The skin in the region of buboes and on the head, arms, neck, and shoulders may show hæmorrhages, which arise from the action of the toxins upon the endothelial cells of the vessels. These cells increase in size, and perhaps in number, and some macrophages arise, after which they degenerate, and allow hæmorrhage by rhexis to take place. These hæmorrhages therefore may be petechial or diffuse, and will contain bacilli. Besides these, however, vesicles, pustules, or carbuncles may be seen.

The vesicle arises from the irritation caused by the bacilli in the skin, producing inflammation with exudation, which may go on to pustulation, or, the vesicle drying up, the cutis may become much inflamed and degenerated, forming the so-called carbuncle, which in no respect resembles a true carbuncle.

The primary bubo shows a periglandular infiltration, which may spread from the site of the enlarged glands in all directions. When this gelatinous exudate is cut into, the enlarged glands can be seen matted together, grey or yellowish-grey in colour, with a soft centre and numerous hæmorrhagic spots, or perhaps large hæmorrhages. The secondary buboes are seen to consist of degenerated glands without the œdema, but with endo- and periglandular hæmorrhages. The tertiary buboes contain hard hyperæmic glands marked by hæmorrhages.

The muscles of the body, but especially those of the abdominal wall, will be seen to be hæmorrhagic. The spleen is enlarged and congested, and shows hæmorrhages, and contains bacilli. The liver may be slightly enlarged and hæmorrhagic, with cloudy swelling, and fatty degeneration of the cells. The lungs usually show some bronchitis, and often patches of secondary broncho-pneumonia. The right heart is usually dilated, and the musculature shows fatty degeneration, cloudy swelling, and hæmorrhage. Primary broncho-pneumonia may, however, exist, and be followed by a septicæmia and bubo formation. The stomach is hyperæmic and hæmorrhagic, while the solitary glands and Peyer's patches of the intestine are swollen, and the mesenteric glands enlarged. The kidney may be normal, or show hæmorrhages. The nervous system seldom shows any changes, but hæmorrhages and meningitis may occur.

Symptomatology.—The incubation period varies from two to ten days, the average being three days. During this period there may be prodromal symptoms in the form of general malaise, headache, gastro-intestinal disturbance, pain, or feeling of discomfort in the site of the future bubo, chilliness, giddiness, and mental dulness.

The onset is usually sudden, with rise of the temperature to 103° F. to 104° F., pulse of 120, and respirations 30 to 40, and marked prostration, with an aggravation of the prodromal symptoms—*i.e.*, severe headache, furred tongue, vomiting, diarrhœa, pains in the back and limbs and at the site of the future bubo, marked chilliness or a rigor, staggering gait, and marked mental dulness.

In a few hours the disease becomes properly established, when the patient presents a typical facial expression of fear or anxiety, the eyes being bloodshot, bright, and staring, the face drawn, and the nostrils dilated. The temperature rises during the first day, but may remit a degree or so on the second day, but if so, it rises quickly again to the same or a higher degree than at first. As a rule, however, the temperature is most irregular. Towards the end it may fall by lysis, if recovery is to take place, or fall rapidly to normal or subnormal, and then as rapidly rise to about 107° F., or may simply rise directly to about 107° F., and death ensue. There is much thirst, and the tongue is coated at first with a whitish fur, but later it becomes covered with sordes, as do the teeth and lips. Vomiting is frequently met with, as well as diarrhœa; but the abdomen is not tender, unless there are enlarged abdominal glands. The spleen is always, and the liver often, enlarged. Cardiac dilatation is an important feature of the disease, and systolic murmurs may be heard. The pulse is rapid, reaching 120 to 180 early in the disease, and later becoming, in bad cases, not countable. At first it is full and of moderate tension, but later it becomes small, weak, and intermittent.

The coagulation of the blood is diminished. Plague bacilli can be found culturally in about a third of the cases examined. The number of erythrocytes and the amount of hæmoglobin are distinctly increased above the normal, and there is a great leucocytosis—*i.e.*, 90,000 to 100,000 and more—but in the septicæmic form there may be a leucopænia. The leucocytosis is almost entirely due to an increase in the polymorphonuclear leucocytes.

The breathing is rapid, and the breath sounds harsh, with moist râles, but signs of lobular pneumonia and pleuritis may also occur. The sputum in this type of pneumonia is very hæmorrhagic and full of bacilli.

Buboes of varying sizes may be noted in the groin, the axilla, or the neck, and are very painful, respectively causing the patient to lie with the leg drawn up close to the chest wall, or the head bent towards the affected side. They usually appear during the first twenty-four hours, and they may decline or suppurate.

The skin is hot and dry, and may show vesicles, pustules, or areas of necrosis, often called 'carbuncles' (they are, of course, not true carbuncles). Hæmorrhages, in the form of petechiæ or ecchymoses, may be seen under the skin, and epistaxis, hæmatemesis, melæna, and hæmaturia may occur.

The quantity of urine is usually diminished, and the specific gravity is high, and plague bacilli may be found. If hæmorrhages have occurred in the urinary tract, there will be erythrocytes and leucocytes, with albumin and globulin, though, apart from this, there is often a trace of albumin present, while anuria is generally present before death. Pregnant women always abort.

As the disease progresses the patient becomes weaker and weaker, the mind wanders, and a wild delirium may occur; but later a low muttering delirium passes into coma, and death ensues from the third to the fifth day. In favourable cases the tongue becomes moist and clean, the temperature declines by lysis, the pulse-rate diminishes, and convalescence begins, but may be much prolonged by suppuration of the buboes or a secondary septicæmia. Even now death may occur from cardiac failure, suppuration, septic infection, or secondary hæmorrhage.

Varieties.—Four variations of the disease are recognized: (1) The ambulatory type; (2) the bubonic type; (3) the septicæmic type; and (4) the pneumonic type.

The Ambulatory Type.—This is the mildest form of the disease, and is characterized by but little fever, with slight enlargement and tenderness of a group of lymphatic glands. If the area of skin drained by these glands is carefully investigated, a primary vesicle will often be seen at the site of the inoculation, and considerably helps in the diagnosis, for its fluid contains typical bacilli. The symptoms of this type resemble those already described as prodromata.

The Bubonic Type.—This type agrees with the general description, the bubo being usually in the groin, less commonly in the axilla, and least commonly in the neck. The fever reaches its maximum on the fourth to fifth day, and lasts till the seventh to tenth day, when it falls by lysis, though it may rise again if suppuration is taking place in the buboes. The attitude of the patient depends upon the position of the bubo, as described above.

The Septicæmic Type.—Here the onset is sudden, and the temperature high, with very rapid pulse, marked prostration, and delirium. Vomiting is severe, and diarrhœa, with motions mixed with blood, not uncommon. Hæmorrhages occur in the skin and from the regions indicated above, and death rapidly takes place in from eighteen hours to three days.

The Pneumonic Type.—There are two distinct types of pneumonia in plague—a pneumonia secondary to bubonic plague and a primary pneumonia. This latter begins without prodromata and with high fever, which continues in a very irregular manner. The breathing is very rapid, and dulness may or may not be present over the bases; the breath sounds are usually tubular and crepitant, and sibilant râles are heard, while the vocal fremitus is increased. Dyspnœa and cyanosis are early marked features, as is the fluid bloody sputum which is found by the second or third day, and is full of bacilli. Pleuritis, with its usual symptoms, may also occur. Prostration is extreme; the heart becomes very weak and the pulse rapid, while the spleen enlarges quickly. This is a very fatal type of the disease, death occurring about the second to the fifth day.

Sequelæ.—Cardiac weakness, with proneness to syncopal attacks, paralyses, septic infections of the buboes, or a general septic infection, or gangrene of the lung, may occur.

Diagnosis.—Difficulty may arise in the diagnosis between the bubonic type of plague and climatic, venereal, and symptomatic buboes; between pneumonic plague and ordinary pneumonia; and between septicæmic plague and various fevers.

In venereal bubo there will be found ulcers on the genital organs, or, at least, the patient will give a history of such. In climatic buboes and various symptomatic buboes due to small ulcerative lesions on the legs, etc., the general condition of the patient is usually far from being so grave as in plague. In any doubtful case bacteriological methods should be employed. A little of the fluid from the suspected bubo is withdrawn, under aseptic precautions, by means of a sterile syringe, and films are made and stained with methylene blue, diluted carbol-fuchsin, or Leishman's stain. The presence of bipolar-staining bacilli is sufficient, for all practical purposes, to consider the case one of plague, though it is desirable, whenever possible, to complete the investigation by cultural methods.

In pneumonic plague the expectoration is generally fluid and greatly hæmorrhagic; the examination of the sputum* will reveal the presence of numerous plague bacilli, easily distinguishable from the pneumococcus by their being Gram-negative.

Septicæmic plague may be distinguished from malaria by the absence of Laveran's parasites, from relapsing fever by the absence of spirochætes, but it is to be noted that cases of mixed infection occur. In India, as observed by Polverini and others, cases of mixed infection of plague and relapsing fever are not rare. The diagnosis between septicæmic plague and cryptogenic septicæmias due to the pneumococcus and other germs, as well as occasionally the differential diagnosis from typhus and typhoid, may be impossible without a complete bacteriological examination of the blood.

The simple microscopical examination of thick films of blood (Manson-Ross method) for the presence of bipolar-staining bacilli is often a failure. The so-called *dilution method* introduced by Castellani for the search of the *Bacillus typhosus* in the blood of typhoid patients is useful also for the search of the plague bacillus, as proved by Kolle and others: 10 c.c. of blood are collected, under aseptic precautions, with a sterile syringe from a vein, and immediately distributed in several flasks of alkaline broth, each containing 300 cubic centimetres of the medium. In this way the bactericidal substances of the blood are greatly diluted, and the growth of the plague bacillus facilitated. Agglutination tests are not of much use in the diagnosis of plague.

Prognosis.—Simpson quotes Procopius of Cæsarea as saying, with regard to the plague in Byzantium, that many whose death the physicians predicted recovered, while those who were supposed to be about to recover often quickly died, from which it may be inferred that the prognosis in cases of plague has to be most guarded, for dangers are numerous even in convalescence—*e.g.*, cardiac failure.

The prognosis varies with the character of the epidemic, some being milder than others, and is better when the number of cases is declining. It also varies for the type of the disease, being best for the ambulatory and worst for the pneumonic. As 75 per cent. of the deaths occur before the sixth day, after that time the prognosis improves.

A good pulse, a clear mind, a normal quantity of chlorides and no albumin in the urine, are good signs. High fever, rapid, thready pulse, violent delirium, sudden fall in the temperature, disappearance of the buboes on the fourth or fifth day, and anuria, are bad signs. But in all cases be cautious about the prognosis, and remember the physicians of Byzantium.

Treatment.—The treatment should aim at killing the bacillus and neutralizing its toxins, and naturally one hopes to find those requirements supplied by sera. Unfortunately no such serum has as yet been found, though encouraging reports have been recorded by Choksy and Polverini concerning Yersin's and Lustig's sera, and by others concerning Cruz's serum.

Yersin's serum is prepared by the inoculation of horses with fresh agar cultures, and is such that 0·1 c.c. should protect a mouse from a dose of bacilli, which otherwise would kill it in two to three days. The dose for man is 60 to 300 c.c., given intravenously and also subcutaneously near the buboes. Lustig and Galeotti's serum is prepared by injecting a horse with a vaccine which contains nucleo-proteid from cultures. The mode of action of these sera is said by some not to be bactericidal, but to encourage phagocytosis.

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* Instead of the sputum, the lung juice, obtained by puncture with a sterile syringe, may be examined.

Though admitting that the serum treatment is far from being perfect, we advise its use at the very beginning, as it gives somewhat better results than the ordinary symptomatic treatment or the so-called antiseptic treatment, such as the internal administration of carbolic acid.

As regards the symptomatic treatment, the first indication is to keep the patient in bed, because of the danger of syncope, and to give him good nursing and fresh air. Fever must be treated by sponging and cold applications; buboes by cold applications and ichthyol, and when they suppurate an incision must be made, and the wound treated aseptically. Not much good is to be obtained by excising the glands even in an early stage, though several authors—*e.g.*, Terni—have recommended it. The heart's action must be maintained by digitalis, strophanthus, and strychnine. Restlessness may require a hypodermic of hyoscin; hæmorrhage will require treatment by calcium chloride; the so-called carbuncles must be treated antiseptically; pneumonia and bronchitis require the ordinary treatment; and if there is constipation, calomel and a saline purge may be given; while vomiting is to be treated as described under Malaria. A sufficiency of fluid should be given, so as to keep up the action of the kidneys.

The diet should consist of broths and milk, while stimulants are usually required.

Prophylaxis.—*Bacillus pestis* being conveyed by the rat-flea from rats to man as a rule, and more rarely from man to man, it is obvious that prophylaxis must include methods directed against rats and fleas, and methods for the protection of human beings.

The spread of the disease from place to place is thought to be mainly by the flea being carried by human beings on their person, or in their clothing, or by means of the merchandise, or by rats.

The prophylaxis will be considered under two headings—Public Prophylaxis and Personal Prophylaxis.

PUBLIC PROPHYLAXIS.—It is necessary, in order to prevent a country from being infected with plague, to institute a Sanitary Service, which should consist of a central authority for collecting and dealing with information on a large scale, and to which will be attached bacteriologists, who will carry out the necessary bacteriological examinations and prepare prophylactics; and a Port Sanitary Branch, for investigating and disinfecting ships.

It is as well, if possible, to limit the communication with infected areas to as few ports as possible, and to provide isolation hospitals for the sick, and for the healthy coming from infected areas. The length of quarantine is fixed at present at five days, but this appears to be too short, if the findings of the Indian Commission with regard to fleas are considered.

Attempts can be made to prevent the disease crossing land frontiers by the medical inspection of persons coming by rail, road, or river, but this method of prophylaxis is liable at any time to break down.

It would appear most necessary to disinfect the clothing and persons of all people coming from infected areas, as they may carry fleas, and this is most difficult to effect; but it is not so difficult to disinfect merchandise by Clayton's apparatus.

In addition, rats must be caught regularly in places situated in danger zones, and inspected to see if any are becoming diseased, for the epizoötic begins before the epidemic.

But of all things the most difficult, as well as the most important, appears to be the recognition of early cases, and pneumonia, buboes, and sudden deaths must be regarded with the greatest suspicion.

When an epidemic begins, there are two periods, as Simpson points out, at which the populace takes fright, and has to be firmly handled: one at the beginning, and the second when the deaths begin to increase rapidly in number. Riots and assassinations of magistrates, medical officers, and inspectors may occur, and must be foreseen.

As diagnosis is so difficult at first, a house-to-house inspection by competent medical officers will be necessary to find out the number of cases, and in no instance must a body be allowed to be buried without being viewed by a medical officer. If this is not done, it will be impossible to gauge the extent of the disease.

Rats must, of course, be regularly and systematically examined, and their mortality curves constructed. The sick must be isolated, and the persons and clothing of contacts disinfected to kill the fleas. Every infected house must be disinfected by filling the adjoining houses with the gas from Clayton's apparatus, and after this the house itself. If this method is not carried out, the rats will simply pass from the infected to the non-infected houses, and spread the plague. Village houses might be burned, which is cheaper and a fairly effective method, though, of course, the rats will escape. The gas in question is generated by burning sulphur at a very high temperature in a special apparatus, when SO_2 and SO_3 and some unknown gases are evolved, which are passed into the ship, house, warehouse, etc., and drawn through by an exhaust-pipe until a 3 per cent. mixture of gas and air comes out, when the exhaust is stopped, and gas passed in until 10 to 12 per cent. is reached, at which it is allowed to remain for four hours. This gas kills rats, rat-fleas, and other insects, and plague bacilli, and if dry, will not injure food-stuffs, except fruit and some vegetables, nor will it harm merchandise or machinery. A mixture of equal parts of cyllin and petrol constitutes a reliable pulicide and bactericide.

Rats may also be killed by means of Danysz's virus, which is a bacillus easily recognized from *Bacillus pestis*, and kills the rat by a septicæmia, causing œdema of the intestinal walls, infiltration of Peyer's patches, and enlargement of the spleen, with sometimes peritonitis, and only then enlargement of the lymphatic glands. Danysz's virus is administered by Simpson's method on bread, and is said not to affect human beings, though recently complaints of illness of persons living in places where some sort of virus was being used has been recorded.

Bannerman has recently strongly advised cats as a method of rat extermination.

PERSONAL PROPHYLAXIS.—Ever since the middle of the eighteenth century there has been an idea that a vaccine should be obtained for the purpose of protecting the individual. Weszpremi and, later, Samoilowitz and Cerutti tried artificial inoculation, but the results were by no means satisfactory, persons dying from plague as the result of the inoculation. Recently a number of vaccines have been prepared for the purpose of personal prophylaxis, which may be classified into: (1) vaccines composed solely of the chemical products of the bacilli; (2) vaccines composed of chemical products and dead bacilli; (3) vaccines composed of living attenuated bacilli.

Chemical Vaccines.—In 1897 Lustig and Galleotti prepared a plague vaccine, composed of the nucleo-proteids of the bacilli obtained by shaking agar cultures with 1 per cent. caustic potash solution, and after two hours adding 0·5 per cent. acetic acid, and thus obtaining a precipitate of nucleo-proteids. It is administered by subcutaneous or intramuscular injections in doses of from 2 to 3 milligrammes. This method has been adopted in La Plata with success.

Vaccines composed of Chemical Products and Dead Bacilli.—The most important is Haffkine's plague prophylactic, prepared by growing the bacillus for four to six weeks in broth, and then sterilizing at 65° C. to 70° C. for one hour, and then decanting into bottles, with or without the addition of a little carbolic acid. The dose for an adult man is 3 c.c., for an adult woman 2 to 2½ c.c., and children in proportion to their age (or size). The injection is made subcutaneously into the arm or loin under the strict antiseptic precautions. Three or four hours after inoculation the temperature rises, and in twelve hours reaches 102° F. to 103° F., while tenderness and swelling may occur at the site of the inoculation, and malaise and general discomfort be felt, which disappear in one to two days, and the swelling in about a week or so. There is no doubt of the benefit of this prophylactic, which gives protection for a considerable number of weeks, and perhaps months. Haffkine considers that the active principle lies in the liquid, but it appears more likely that it is in the dead bacilli.

The German Plague Commission used a growth of the bacilli on agar killed by heating to 65° C., and then suspended in normal saline, to which 0·5 per cent. carbolic acid was added.

Terni and Bandi used the sterilized exudate from the peritoneum of guinea-pigs inoculated intraperitoneally with plague bacilli, and killed some little time before they would have died naturally. The exudate is diluted with a solution of carbolic acid and sodium carbonate and chloride, and given in a dose of 1·5 to 2·5 c.c. By this method plague aggressions are produced and used.

Klein has advocated an 'organ prophylactic,' obtained by drying and powdering buboes, spleens, lungs, and livers of infected animals. The dose for an individual is from 5 to 7 milligrammes, made into an emulsion with warm, sterile, distilled water, and injected subcutaneously, but it has not yet been tried on man as far as we know.

Vaccines composed of Living Attenuated Bacilli.—Strong and Kolle have recommended the use of living virulent cultures, and Strong has practically shown that this method of vaccination can be carried out without danger. This vaccination consists of the intramuscular injection of one whole twenty-four-hour agar slant of the living virulent culture in an adult, and one-quarter to one-half of such a culture in a child. The reaction is not excessive. About ten days after the inoculation Strong has observed a marked rise in the opsonic index, and that the phenomenon of complement fixation is given by the blood-serum, thus proving the presence of specific antibodies.

Strong and Kitasato are of the opinion that Governments should unite to deal with plague by attacking it in the endemic centres by general vaccination of the population.

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CHAPTER XXXIII

THE UNCLASSIFIED AND COSMOPOLITAN FEVERS IN THE TROPICS

General remarks—Seven-days fever—Three-days fever—Hyperpyrexial fever—Double continued fever—Low intermittent non-malarial fever—High intermittent non-malarial fever—Cosmopolitan fevers—Typhus—Psittacosis—References.

General Remarks. — A number of indefinite fevers remain to be described, for, since malaria became a well-defined disease, it has been discovered that there are a number of fevers which were previously confused with it. In 1898 Crombie made an attempt to arrange these fevers in some order according to their clinical symptoms, defining a simple continued fever, which appears to be the same as Rogers' seven-days fever, a low fever, and a non-malarial remittent, which was undoubtedly typhoid. Since then Manson has described a double continued fever, Thompstone and Bennet a hyperpyrexial fever, Rogers a seven-days fever, and McCarrison a three-days fever, and Castellani defined several distinct types of fever in Ceylon, while Cobb has described a fever in Bengal.

This latter is peculiar, and reads like a mild attack of insolation. It occurs in the hottest months of the year. The onset is sudden, the temperature rising to 103° to 104° F., with headache, nausea, and vomiting, associated with a peculiar pigmentation of the nose and cheeks. The fever is continued, and lasts eight to ten days. It requires further investigation.

A peculiar form of continued fever, which is said not to be typhoid and not to be malaria, is described by Robles, of Quezaltenango, and Gann, of British Honduras.

Robles has separated from the blood of the patients a micrococcus resembling *Micrococcus melitensis*, but liquefying gelatine. The patients, who are usually derived from the younger members of the poorer classes, are anæmic and debilitated, and live under insanitary conditions. The fever is very irregular, being at first remittent, but becoming intermittent, while the periods of apyrexia increase in length and frequency as the disease progresses. The symptoms are but slight, consisting of headache, malaise, furred tongue, thirst and anæmia, with slight constipation. The spleen is either not enlarged or but slightly so, while the liver is a little tender on firm pressure. The duration of the disease is from two to three weeks to several months. Convalescence is long drawn out, there being much debility and disinclination for mental or physical exertion. The prognosis is good, as recovery is the rule. The best treatment is change to a cooler climate, good sanitation, a light, nourishing diet, and a tonic of iron and strychnine.

Forrest has described a fever in Rangoon which he called 'Rangoon local fever,' which lasts three to fifteen days, and shows a temperature curve resembling a parabola, ascending and descending gradually. The maximum temperature is 104° F., and the blood shows a polymorphonuclear leucocytosis.

We shall now describe some of these indefinite fevers, and also give brief descriptions of typhus fever and psittacosis.

SEVEN-DAYS FEVER.

Synonyms.—Simple Continued Fever, Febricula.

Definition.—A specific fever of short duration, and characterized by a sudden onset, a saddle-back remission of the temperature, a slow pulse, with a leucopenia due to a polymorphonuclear decrease.

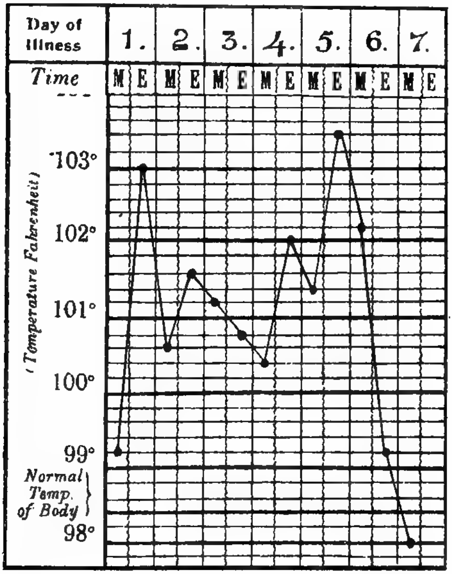

FIG. 301.—TEMPERATURE-CHART OF A CASE OF SEVEN-DAYS FEVER.

History.—This disease was clearly differentiated from the mass of unclassified fevers by Rogers in 1905-08 as a sporadic fever of Indian seaport towns. It is probably identical with Crombie's simple continued fever, and, according to several observers, is a form of dengue.

Climatology.—So far in India and Ceylon it has been found in towns in low-lying districts near the sea, and is believed not to spread inland. In Calcutta it occurs from May to September, and is very common in Colombo during the same months.

Ætiology.—Rogers found a motile bacillus related to the coli bacillus in the blood, which he thinks may possibly be the cause of the disease. It resembles the *Bacillus coli communis* in size and shape, and possesses flagella ; is decolourized by Gram ; produces a diffuse haziness in broth; slowly liquefies gelatine; grows on agar like *B. coli;* does not produce gas in glucose agar; nor gas, nor acid, in dextrose, lævulose, and maltose broths; nor does it ferment arabinose, galactose, saccharose, lactose, inulin, salicin, erythrite, mannite or dulcite. It is agglutinated in 1 in 20 and 1 in 40 dilutions of the serum of seven-day fever patients. These observations have not yet been confirmed. Clayton suggests that the disease is carried by mosquitoes. The fever is commonly found among Europeans, and especially among people having to do with shipping, and also in new-comers.

Pathology.—If the above organism is proved to be the cause of the fever, then the disease is a form of septicæmia. The morbid anatomy is unknown, as the mortality is nil.

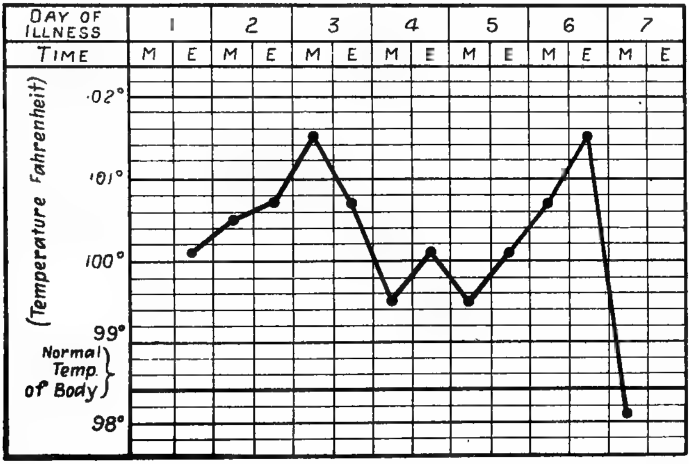

FIG. 302.—TEMPERATURE-CHART OF A CASE OF SEVEN-DAYS FEVER.

Symptomatology.—The incubation period is unknown, and no prodromal symptoms have been recorded. The invasion is sudden, with a rapid rise of temperature to 102° F. or 105° F., but the pulse is not as quick as it should be, compared to the temperature.

The face is flushed, and the palpebral conjunctivæ injected, and some rose-coloured spots may appear on the skin. Pain is felt in the back and, less commonly, in the limbs. After the initial rise there is usually a gradual marked remission of the temperature for two to three days, when the fever again rises, producing the typical saddle-back remission. After the second rise the temperature gradually or quickly falls to normal, and the disease ends about the seventh to eighth day. There is generally frontal headache, and the tongue is furred on the dorsum, while the edges are red. Nausea and vomiting are not common; the bowels are usually normal, though constipation or diarrhœa may occur. The abdomen is often distended, and may be painful. The liver is usually normal, but may in a few cases be slightly enlarged, and the spleen is at times enlarged. The respiratory and circulatory organs are normal, except that the pulse is often slow as compared with the temperature.

The blood shows a slight reduction of the erythrocytes and a marked leucopenia—2,000 to 4,000 per c.c. The polymorphonuclear leucocytes are reduced, and the lymphocytes and mononuclears are increased. Nothing abnormal is found in the urine, except the usual appearance of febrile urine.

Rashes are not rare. The most common is a mottling or a diffuse erythema of the extensor surfaces of the forearms on the fourth to sixth day, which fades before the temperature falls.

There are no complications or sequelæ, and the prognosis is excellent, as the mortality is nil. Mild recurrences in following years may be met with, but relapses in the same year, though rare, do occur, as we have met with such a case. Convalescence is rapid.

Diagnosis.—It can be distinguished from malaria by the absence of parasites, and the slow pulse with high fever ; from influenza by the absence of respiratory symptoms ; and from dengue by the absence of the typical rash, of the joint pains and by the slow pulse.

Treatment.—This is purely symptomatic.

THREE-DAYS FEVER.

A fever exists in Upper India which appears to have first been noted by James at Mian Mir, but it was really differentiated by McGarrison in Chitral in 1906, where it has prevailed among the troops since 1895. It appears to attack new-comers and young people most commonly, and is more prevalent among Europeans and Goorkhas than among Hindus.

Climatology.—It appears to depend in some way upon high air-temperatures, but other atmospheric conditions are not important.

Ætiology.—It is not contagious, but it is very infectious, for a visit of even a few hours to the infected district in the right season will cause the disease. No bacterium nor animal parasite has been found in the blood or urine, or obtained by splenic puncture, and further subcutaneous and intravenous injections of blood from fever cases into healthy individuals have been without result. It has, however, been noted that its appearance coincides remarkably with that of the sand-fly, which is therefore suspected of being a possible agent in its spread.

Pathology.—As the causal agent is unknown and the morbid anatomy is unknown, because the mortality is nil, no remarks can be offered as to the pathology.

Symptomatology.—The incubation varies from a few hours to five, rarely six, days. Prodromal symptoms in the form of malaise, vague pains, discomfort, and weariness, are generally present.

The onset is sudden, with a slight rigor or a feeling of chilliness and severe frontal headache, lumbar and body pains. The conjunctivæ are injected and the cheeks slightly flushed. The skin is hot and dry, and the temperature rapidly rises to reach 104° F., or rarely 105° F., in twenty-four hours. The pulse may reach 100 to 116, but is often unduly slow. The patient is very irritable, and intolerant to sounds. Movements of the eyes are painful, and sleep is impossible.

The tongue is coated on the dorsum with a white or brown fur, and the edges may be red. The appetite is lost and the sense of taste destroyed, but vomiting is uncommon, though there is pain in the epigastrium and sometimes diarrhœa. The mouth and throat are congested and irritable, and there may be a little bronchitis. The cough is generally dry, with thick, tenacious, muco-purulent expectoration. The tonsils are enlarged and the uvula congested. The liver and spleen are normal. Vertigo may be present, and pains in the joints, especially in the elbow and knee, as well as in the bones and muscles, and burning sensations in the palms and soles. Cramps are not uncommon.

The blood shows a marked leucopenia—4,000 leucocytes per c.c.—and the differential count is as follows:

	Per Cent.
Polymorphonuclears	61·7
Lymphocytes	21·3
Mononuclears	14·0
Eosinophiles	2·7

The urine is diminished in quantity, but is of normal colour, specific gravity, and acid reaction, and does not contain albumin.

In thirty-six to forty-eight hours the temperature falls slowly to normal, but may show a terminal rise. This fall is often accompanied with epistaxis, more rarely with sweating, vomiting, or diarrhœa. When the temperature falls the symptoms abate, but much weakness is felt, the convalescence being prolonged. An afebrile variety, with only headache and body pains, is described.

Complications.—The complications are bronchitis and phlebitis.

Sequelæ.—Pains in the bones and a peculiar loss of memory may be sequelæ.

Prognosis.—No one has been known to die of this complaint.

Diagnosis.—This has to be made in much the same way as in seven-days fever, from malaria, influenza, and dengue. This fever closely resembles the three-days fever described in Malta by Gerrard, Birt, and others, which is identical with the three-days fever of Dalmatia and other parts of Austria-Hungary, which is known under the name of 'pappataci fever.' Pappataci is the local name of a dipterous insect, *Phlebotomus pappatasii*, which is the carrier of the unknown cause of the disease.

Treatment.—The treatment is purely symptomatic: rest in bed, plenty of water to drink, cooling applications, and a most restricted liquid diet.

HYPERPYREXIAL FEVER.

There is a peculiar form of fever which we met with in 1897 in two cases on the Gold Coast, and which was first described by Thompstone and Bennett in Southern Nigeria, in which the patient begins with a mild fever which looks like a typical malarial attack, the temperature falling after the ordinary sweating stage, though no malarial parasites appear in the blood. The next day the temperature is almost normal, and no anxiety is felt about the patient. But on the third day the temperature begins to rise, and reaches 104° F. to 107° F., at which it will remain if only drugs are used; but if cool bathing is resorted to, the temperature will fall temporarily, rising in due course until cool bathing is again performed. This struggle continues, despite any medical treatment that may be employed, until, at the end of six to seven days, the cool bathing ceases to have its effect, and the temperature goes on until 110° F. is reached about the eighth day, and the patient, after having been delirious, becomes comatose and dies; or, in about 50 per cent. of Thompstone and Bennett's cases, the temperature remains at about 105° F. for three weeks, and then gradually falls to normal about the sixth week.

The spleen, liver, abdominal organs, urine, and blood appear quite normal, except that coagulation is said to be quick. The conjunctivæ are injected, and the mind is clear until the terminal delirium sets in. It was not possible to obtain a post-mortem in the cases which we saw. The ætiology is quite unknown.

Treatment.—Cool sponging, cool baths, and cool packs are the only useful treatment.

DOUBLE CONTINUED FEVER.

This disease was first met with by Manson, and subsequently by Thorpe and Rousseau in China.

The disease begins insidiously, the temperature rising to 104° F. and remitting about 3° F. per diem, with slow pulse, a moist red tongue, and constipation. The spleen is slightly enlarged, and all the other organs are normal. After ten to fifteen days the temperature falls gradually by lysis to normal, at which it remains for two to seven days, when a second paroxysm of fever sets in of the same type as the first, only lasting some ten days, after which the patient becomes convalescent. There is, however, a considerable amount of anæmia, and it is a long time before the strength is regained. There are no complications or sequelæ.

Treatment must be symptomatic; quinine is useless.

LOW INTERMITTENT NON-MALARIAL FEVER.

This fever has been described by Castellani in Ceylon. Cases of apparently identical nature have been later observed by Murray in Siam. The onset of the disease is insidious, or it may follow what to all purposes appears to be a mild attack of influenza, the patient feeling out of sorts, feverish, and complaining of muscular rheumatoid pains all over the body. The type of the fever is intermittent. Every day, generally between the hours of ten and twelve, the patient feels somewhat chilly, but there is no shivering fit. The temperature rises, the maximum varying between 99° F. and 102° F. The temperature never rises, in our experience, above 102° F. In the evening, between eight and midnight, the temperature slowly decreases and becomes normal. Occasionally the patient may perspire when the temperature falls, but this is not a constant symptom. The physical examination of the patient will reveal nothing abnormal, apart from, occasionally, signs of slight anæmia. The liver and spleen are not enlarged. In a few cases some superficial lymphatic glands may be slightly enlarged. In some cases the red blood cells are decreased. An interesting feature in most cases is the distinct increase in the number of eosinophile leucocytes, even when no evidence of intestinal worms can be found in the

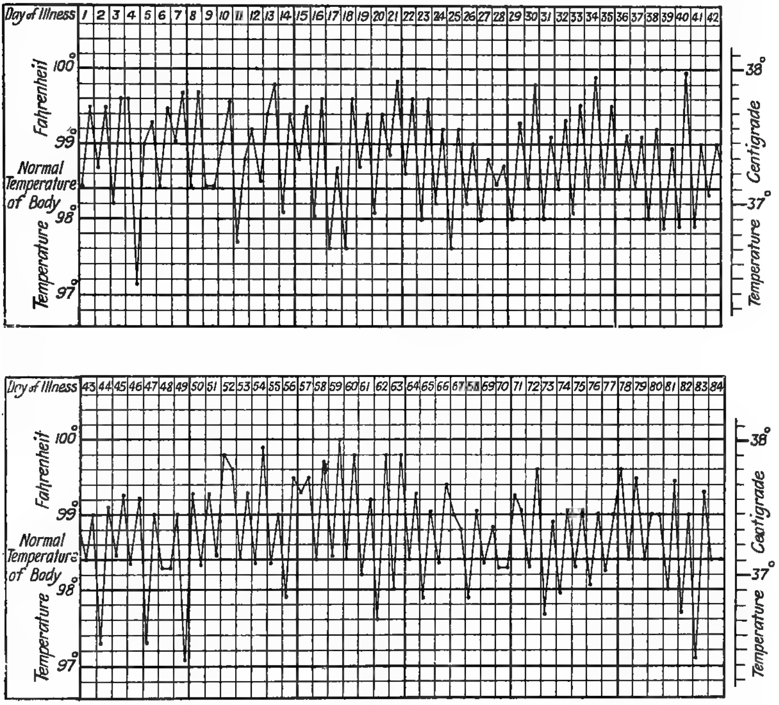

FIG. 303.—TEMPERATURE-CHART OF A CASE OF LOW INTERMITTENT NON-MALARIAL FEVER.

motions. The course of the fever is very long. We have seen cases lasting six months.

Diagnosis.—This fever may be diagnosed from *Malaria* by the absence of Laveran's parasites, and by the fact that the spleen is not enlarged; from *Malta fever*, a type of which it closely resembles clinically, by the absence of the *Micrococcus melitensis* in the blood, and the constant negative result of Wright's reaction; from trypanosomiasis by the absence of the *Trypanosoma gambiense*.

Prognosis.—This is good—*quoad vitam*—but the patient feels weak, tired, nervous, and unfit to do his work properly for months.

Treatment.—A change of climate is always beneficial. A long course of injections of quinine cacodylate is useful in many cases. The ordinary preparations of quinine by the mouth or by injection do not influence the fever in the least.

HIGH INTERMITTENT NON-MALARIAL FEVER.

This has often been observed in children. Apart, perhaps, from slight anæmia, the child does not show any symptoms except the fever. He takes his food well, runs about and plays, and seems apparently in his usual health. The fever begins in the late morning, and lasts several hours every day, reaching 103° to 104° F. and more. There is no shivering fit at the onset, nor perspiration when the temperature falls to normal. The blood does not show anything abnormal, except, occasionally, a slight degree of anæmia. The course of the fever is very long, lasting at times several months. Quinine does not influence it in the least. As a rule, a change of climate stops the fever almost immediately.

COSMOPOLITAN FEVERS IN THE TROPICS.

In addition to the fevers peculiar to, or commonly found in, the tropics, many cosmopolitan fevers occur.

Influenza might really be considered to be a tropical disease which has invaded and become endemic in the Temperate Zone; for most epidemics have come from Asia, where it is endemic. Of all the cosmopolitan fevers, the most important to the medical practitioner is typhoid, which is so common in Asia as to almost justify compulsory antityphoid inoculation. This disease is probably mainly spread by flies and contaminated milk, while the bacilli are spread all over a town by means of 'human carriers,' especially where sanitation is defective. Typhoid is a preventable disease, and with improved sanitation will no doubt diminish as much in the East as it has in the West; but at the present time the tropical practitioner has far more experience of the disease than his Temperate Zone colleague. It is very common among natives. In most cases the temperature does not run the typical course described in textbooks on general medicine, having sometimes a high re-

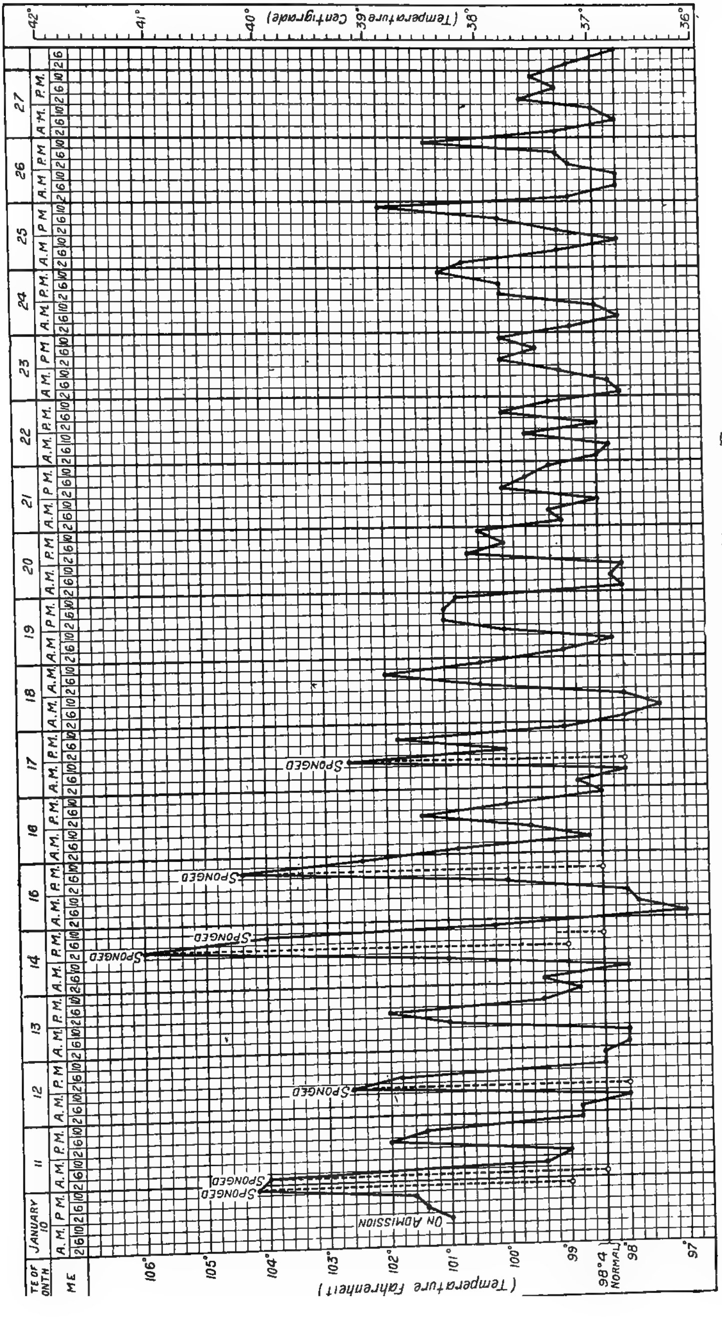

FIG. 304.—INTERMITTENT TYPE OF TYPHOID FEVER.

mittent type, and at others an intermittent type, while cases of mixed infection with malaria are not rare.

Paratyphoid and paratyphoid-like fevers, as described by one of us, are not rare. Some cases have been met with due to a bacillus, *B. ceylonensis* Castellani, which is somewhat different from the paratyphoid bacilli. Cerebro-spinal meningitis is met with apparently throughout the tropics, for it is known on the West Coast of Africa and its hinterland, and in Asia. Its high polynuclear leucocytosis is of importance in its recognition.

Measles, German measles, mumps, whooping-cough, chicken-pox, and smallpox are all met with. Diphtheria is more frequent than generally stated, but is apt to be overlooked, owing to the old belief that it does not occur in the tropics. It is more frequently observed in hill-stations and in the cooler times of the year. Pfeiffer's glandular fever is known, but is rare.

Rheumatism and scarlet fever are distinctly uncommon. Septic infections and intoxications as primary diseases, due to pyogenic organisms, are not uncommon. Erysipelas is often diagnosed, but the symptoms are often not those of the ordinary disease of Europe, being probably due to filariasis or animal stings.

Two cosmopolitan diseases—viz., typhus and psittacosis—may be mentioned in greater detail.

Typhus.

Synonyms.—Spotted Fever, Prison Fever, Fleckfieber, Typhus Exanthématique, Tifo Esantematico, El Tarbardillo, Vlekkoorts, Homma Typhuisa, Synochus Putrida.

Definition.—Typhus is an acute specific fever of unknown cause, said to be very infectious, but in what manner is not known, and characterized in most cases by a sudden onset, a macular petechial eruption, and severe toxæmia, which, after a definite course, generally ends by crisis.

History.—The early history of typhus is wrapped in obscurity by reason of its confusion with plague; for though Hippocrates mentions the word 'typhus,' he applied it to stuporous and delirious conditions, and does not appear to have been acquainted with the fever in question. This confusion with plague continued until Frascastorius, in the sixteenth century, gave such an account as enabled them to be separated from one another, though the nomenclature at first indicated that they were related, and it was not until 1760 that the term 'typhus' was first applied to the disease by Boissier de Sauvages.

During the eighteenth and nineteenth centuries typhus was well known in Europe, but included typhoid and relapsing fevers, from the former of which it was distinguished by a long series of researches, beginning with those of Strother, Gilchrist, and Huxham in the early eighteenth century, and ending with Still's classical work in 1837, while the history of the differentiation from the latter has already been described in the chapter on the Relapsing Fevers.

For a long time the disease passed unrecognized in the tropics, and, indeed, in the *Lancet* of 1871 it is even debated as to whether it could exist in those regions; but though it is impossible to deny that Lyell, in his observations in 1852, mistook relapsing fever for it, and that Fairweather in 1869 was confusing it with typhoid, it would appear as though Lyons, in 1869, clearly recognized the disease as occurring in North-West India, where it is now well known to be endemic, and it has since been reported from many parts of the tropics.

Climatology.—Typhus is essentially a disease of temperate and cold climates, and therefore is well known to occur in Europe and America.

In the tropics it principally appears in places situated at high altitudes, or where there are cool seasons, in which case it disappears in a most remarkable manner as soon as the warm season sets in.

In Africa it is said by Hirsch to be endemic in Nubia, and has been carefully studied in Egypt by Sandwith, where he says that it has been definitely recognized since 1836, and where a few cases are reported every year in the spring months. It is also reported from Tripoli, Tunis, Algeria (rarely), and Morocco. In Asia it appears to occur only in epidemic form in Asia Minor and Syria, but is believed to be endemic in Persia, and possibly also in Afghanistan, because it is said to be regularly imported into India by caravans from this country. In India an endemic area exists on the west of the Indus, stretching from Beloochistan in the south to Yusufzai, Hazara, and Kashmir in the north, and then passing eastwards along the ranges of the Himalayas, where it is especially prevalent at Kulu, and also passing southwards into the district of Rawal Pindi. In Ceylon we have met with a few cases in European sailors, who have, however, acquired the disease elsewhere. It occurs in Indo-China; in Northern China, where it is endemic, becoming epidemic every spring; and in Japan, where it occurs yearly in the province of Hiogo. It does not occur in Australasia or Oceania. In Tropical America it is endemic in Mexico, rare in Central America, absent in the West Indies, the Guianas, Colombia, and Venezuela, and is rare in Brazil, though it is common in Peru and Northern Chili.

Ætiology.—The causation of typhus remains undiscovered, though many researches have been made, first by Hallier, who in 1868 described a fungus as the causal agent; and then by Klebs, who found bacilli in 1881; and by Mott and Blore, who in the same year described minute screw-like, motile organisms as present in the blood during life, and micrococcal-like bodies found in cells between the muscular fibres of the heart after death.

In 1891 Hlava described ovoid bodies which he believed to be part of a strepto-bacillus; in 1892 Thoinot and Calmette saw flagellate bodies; and in 1892 Lewaschew found a motile organism, sometimes like a thread, sometimes oval and flagellate; in 1893 Dubieff and Brühl described a diplococcus; in 1899 Balfour and Porter found another diplococcus. In 1903 Gottschlich described a *Babesia* existing in non-motile endocorpuscular and flagellate free forms in cases in Egypt, but these parasites may have only been cellular degenerations; and, lastly, Horiachi described a bacillus which he isolated from the fæces and urine of Japanese troops which in the war in Manchuria suffered from a disease which was probably typhus. Krompecher, Goldzieher, and Augyán have described intracorpuscular bodies somewhat resembling a *Babesia*. Yersin and Vassal, in 1908, succeeded in communicating the disease directly from one man to another by inoculation, but failed to reproduce it in rats, guinea-pigs, and rabbits. Their experiments tend to prove that the infective agent exists in the blood from the second to the fifth day of the disease. Nicolle has experimentally infected monkeys.

With regard to the spread of the disease, there is a great conflict of opinion as to whether it is infectious; most certainly it does not cross air-spaces, though it seems to be associated with bedding, fomites, furniture, and dirt, which causes the suspicion that the agent may be an animal parasite. Moreover, the fact that it only appears in the cool season of the tropics, and its rapid disappearance in the warm season, is also in favour of its transmission by some animal. Therefore suspicion is aroused that it may be spread by a blood-sucking parasite, perhaps an insect.

Patton has recently shown that *Cimex lectularius* Linnæus 1758 is found along the north-west frontier of India; and Husband and MacWalters draw attention to the fact that the distribution of this bug curiously coincides with the distribution of typhus in India.

These latter observers point out that in an epidemic occurring in a gaol, the hospital was found infected with bugs, which occurred nowhere else. On the destruction of these pests the epidemic ceased. Moreover, they draw attention to the fact that predisposing causes of typhus, such as dirt, overcrowdng, and the way in which the infection hangs about bedding, buildings, and furniture, are easily explicable on the bug hypothesis. Sambon, in his article on Rocky Mountain fever in Allbutt and Rolleston's 'System,' advances arguments in favour of the identity of Rocky Mountain and typhus fevers; but Husband and MacWalters' researches are not in favour of a tick being the carrier of the disease. It may be that typhus and Rocky Mountain fevers are caused by allied protozoan parasites spread by different bloodsuckers. In Glasgow the flea was suspected to be the cause of the dissemination of the disease. Nicolle suspects *Pediculus vestimentorum*.

Pathology.—The cause being entirely unknown, the pathology can be but briefly mentioned. The infective agent exists in the peripheral blood from the second to the fifth day, and probably is also found in the enlarged and congested spleen. After the fifth day it is not known what definitely happens to it, but the eruption appearing about that date leads to the belief that it enters the skin.

Morbid Anatomy.—The spleen is enlarged and engorged if the post-mortem takes place up to the middle of the second week, but not later. There is œdema of the lungs and hypostatic pneumonia, cloudy swelling and fatty degeneration of the heart, cloudy swelling of the liver and kidneys, and hyperæmia of all the organs.

Symptomatology.—The incubation period of the naturally acquired infection is not well known at present, varying from four to eighteen days, but more probably being about eight to twelve days.

Prodromal symptoms are often entirely absent, or consist of vague feelings of fatigue, giddiness, and headache.

The onset is sudden, being characterized by frontal headache, pains in various parts of the body, of which pain in the chest, giving rise to the suspicion of pneumonia is important; marked rise of temperature from 101° F. to 104° F.; quick pulse (100 to 120); flushed face and suffused eyes; quickened respirations, and a sensation of great weakness. During the next two or three days the temperature continues to rise at night; with remissions in the morning, to a maximum of about 104° F. to 105° F. on the second to fourth days, during which time the tongue becomes dry, swollen, and cracked, with a thick brown deposit on the dorsum, while the tip and sides are red; nausea may be experienced, but vomiting is rare, and the bowels are either constipated or normal.

The nervous system is early affected, the patient being apathetic, drowsy, with a dull expression. The changes in the blood are of the utmost importance, and should be carefully studied. There is always an increase in the red cells, with a corresponding increase in the hæmoglobin, and a leucocytosis, which is usually well marked, being on an average about 24,000 per cubic millimetre, but varying between the extremes of 8,000 and 54,000. The differential leucocyte count is also of importance, for in cases uncomplicated with malaria or other protozoal infections the polymorphonuclear increase is a characteristic feature, and may exceed 90 per cent.; while the mononuclears and lymphocytes may be reduced, especially if the case is to end fatally, while eosinophiles are often entirely absent—a most characteristic feature in a case in the tropics, where worm-infection is common. The mononuclear decrease is, however, not evident in cases about to recover, nor is it present in natives in the tropics, who, of course, are liable to previous protozoal infections, and this may lower the relative polynuclear count in these regions to 60 per cent. or less.

Though there is an increase in the red and white corpuscles, the specific gravity is said to be lower than normal, which is rather extraordinary, and must indicate, if true, considerable alterations in the plasma. As the disease progresses, the rapidity of the pulse increases, and may reach 140 per minute, and is usually small and of low tension. The respirations are always quickened, and there are generally signs of pharyngitis, bronchitis, or bronchopneumonia, while delirium is not uncommon, especially at night.

About the fourth to the fifth day the typical rash appears, which, though easy to see in white or light-coloured races, is very difficult to discern in dark-coloured peoples. There are generally three eruptions: first, a transient erythema ; secondly, a macular, measly eruption, which becomes more or less hæmorrhagic ; and thirdly, the petechial eruption ; but it may safely be said that the first will only be rarely seen in native races, and the second may also not be visible if poorly marked, while the third is known to be absent in mild cases, and therefore in the tropics there may be cases in native races in which no eruption is recorded. Thus, Husband and MacWalters failed to find it in 20 per cent. of their observations, and in but very few of the 80 per cent. in which some rash was recorded was it distinct, and therefore could easily have been overlooked. It appears first on the abdomen or chest, and quickly spreads to the shoulders, back, and extremities, and in well-marked cases will cover the whole body, except the face, palms, and soles. The typical rash is composed of maculæ, but slightly raised, which disappear on pressure, and usually become hæmorrhagic after a couple of days. A petechial eruption may also appear somewhat later, but is often wanting, and when widespread is an indication of a bad prognosis. A miliary eruption may appear later in the attack, and be followed by a desquamation. After the appearance of the eruption the leucocytosis becomes more marked, as do the nervous symptoms, the patient suffering from severe delirium, which may become quite violent ; or he may show a stuporous condition, which becomes a semi-coma, and in fatal cases deepens into a profound comatose condition.

About the eighth or ninth day a pseudo-crisis may be noticed, and later the eruption will be seen to fade and disappear, when the spleen also becomes normal, and the leucocytosis becoming more marked, the skin begins to act vigorously, and the temperature falls by crisis on the tenth to the twelfth day, or by lysis during two days, to normal, and convalescence begins. Usually recovery is quick, relapses being extremely rare. Death may take place during the first week or about the tenth day from toxæmia.

Varieties.—All cases of typhus do not follow the typical course, for mild, ambulatory, and abortive cases are recorded, as are also malignant attacks causing death on the second or third day.

Complications.—The most usual complications of typhus fever are bronchitis and broncho-pneumonia, but relapsing fever, typhoid, and acute miliary tuberculosis may occur.

Diagnosis.—The important diagnostic signs of typhus fever are the leucocytosis, associated with the rash, and the extreme nervous prostration.

Relapsing fever may be differentiated by finding the spirochætes in the blood and by the relapse ; smallpox, by the precursory rashes, the fall of temperature when the true rash appears, and the presence of the eruption on the face ; measles, by Koplik's spots, the coryza, and bronchitis ; cerebrospinal meningitis, by the retraction of the head and Kernig's sign ; pneumonia, by the rusty sputum and the physical signs ; malaria, by the presence of the typical parasites in the blood ; influenza, by the absence of the leucocytosis ; and plague, by the discovery of the bacilli in the buboes or sputum.

Prognosis.—The case-mortality is variously stated as being from 10 to 50 per cent. The signs indicative of serious trouble and grave prognosis are the absence of eosinophiles in the blood, decrease in the number of the mononuclears, slow pulse, severe petechial eruption or nervous symptoms, alcoholism, pulmonary complaints, meteorism, gangrene, and cyanosis of the face.

The signs indicative of a hopeful prognosis are an increase in the eosinophiles and mononuclears, and the absence of the petechial eruption and slight nerve symptoms.

Treatment.—The patient should be placed in an airy, well-lighted room, sparsely furnished, and placed upon a diet of milk, broths, jellies, etc., while plenty of water is allowed to be drunk. Careful attention and nursing are required, especially when delirious. The temperature should be controlled by cool sponging, and the nervous symptoms by ice to the head, hyoscin, bromides, or morphine, while the heart is supported by hypodermic injections of strychnine, digitalin, etc.

Prophylaxis.—The disease is apparently highly contagious, but this probably is due not to direct, but indirect action, through blood-sucking insects ; hence fomites are dangerous, as are bedding, furniture, etc. All rooms should, therefore, be carefully cleaned, and special attention be taken to kill all vermin, but especially bugs, as described in Chapter XIX.

PSITTACOSIS.

Definition.—A very fatal specific epizoötic among parrots, which is capable of spreading to man and causing a febrile condition resembling typhoid fever in its characters, and which is very liable to be complicated with severe pneumonia.

History.—Ritter, in 1879, was the first to suspect that there was a connection between small epidemics of pneumonia limited to certain houses and an illness among parrots in the same houses. In 1880 Eberth obtained large numbers of micrococci from the bodies of grey parrots. Ritter's observations were confirmed by Ost of Berne, in 1882, and by Wagner of Leipsic, in 1885. In 1892, 500 parrots were shipped from South America for Paris, but no less than 300 died *en route* from enteritis. On arrival in Paris the surviving birds were divided into two lots, and sold to various people, with a result that within twenty-six days of their arrival an epidemic of psittacosis broke out, which resulted in forty-nine cases, with sixteen deaths. The epidemic was characterized by being of the *house type*, by which is meant that several persons in the same house were attacked by the complaint.

Smaller epidemics occurred in 1893 and 1894, and in the same year Banti, Malenchini, and Palamidessi reported an epidemic in Florence. In 1895 there were outbreaks at Prato, Cologne, and Paris ; in 1897 at Genoa ; in 1898 at Cologne ; in 1901 at South Elpidio, Ancona, and Hull ; in 1904 at New Hampshire, one of the Eastern United States of America.

Ætiology.—The disease is apparently due to a bacillus belonging to the paracoli group, first isolated from the wings of parrots which had died from the disease by Nocard in 1893, and subsequently found by Gilbert and Fournier in 1897 in the intestine of the sick birds, and also in the heart-blood of a man who died from the disease. The bacillus in question appears to be closely related to, but distinct from, the *Bacillus typhosus* of Eberth, and is pathogenic for parrots and other birds. It is possible that this bacillus exists normally in parrots, and only becomes pathogenic under circumstances of bad hygiene, when it causes an enteritis. The feathers, becoming contaminated with fæcal matter, are cleaned by the parrot with its tongue in the usual way, so that its mouth and bill become infected, and by this means the disease is spread to persons who feed or caress the birds. Very rarely the disease spreads from man to man.

Pathology.—In parrots the disease causes a very fatal form of enteritis. In man it produces a septicæmia, often complicated by a pneumonia, brought about as a rule by the pneumococcus.

The post-mortem reveals lobular pneumonia in the lungs, fatty degeneration of the heart-muscle and liver, enlargement and softening of the spleen, and congestion of the kidneys, with swelling of the tubular epithelium.

Symptomatology.—The incubation period varies from seven to twelve days, after which the disease may begin suddenly with a chill, but more usually commences insidiously, like typhoid fever, with headache, malaise, etc., and a rise of temperature from 102° F. to 104° F., with a pulse-rate of 100 to 120 per minute, quickened respirations, cough, and muco-purulent expectoration. Râles may be heard over the lungs, while the spleen is enlarged, the tongue dry and furred, and diarrhœa or constipation may be present. Rose-coloured spots appear on the skin, and the patient becomes dull and stupid, in which condition he may remain for several days, and as a rule will recover in about fifteen to twenty days if no pneumonic complication intervenes. If, however, pneumonia sets in, the patient becomes much worse, and as a rule dies.

Diagnosis.—The diagnosis is to be made by the discovery of sick parrots in houses in which people are suffering from typhoid-like fevers and pneumonia.

Bacteriologically, attempts may be made to obtain cultures of the bacilli from the blood.

Prognosis.—The prognosis is grave in old people and when pneumonia sets in, the mortality being stated to be about 35 to 40 per cent.

Treatment.—The treatment must be conducted on the lines usually laid down for typhoid fever and pneumonia.

Prophylaxis.—The infected parrots appear always to come from South America; therefore care should be taken that only healthy birds are allowed to be shipped, and that these are kept in good hygienic conditions during the voyage. On arrival at their destination, they should be quarantined for about a couple of weeks, and, if found to be infected, should be destroyed, and their dead bodies and cages burnt. The places in which they were kept should also be thoroughly disinfected. Parrots should not be allowed to take food out of peoples' mouths, and should always be kept in good hygienic conditions.

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SECTION B

GENERAL DISEASES

CHAPTER XXXIV

PARAGONIMIASIS, KATAYAMA DISEASE, AND POROCEPHALOSIS

Paragonimiasis—Katayama disease—Porocephalosis—References.

PARAGONIMIASIS.

Synonyms.—Parasitic Hæmoptysis, Pulmonary Distomatosis, Endemic Hæmoptysis.

Definition.—Paragonimiasis is a chronic or subacute general or local infection of man by means of *Paragonimus westermani* Kerbert, which produces cystic lesions, containing a thick, opaque, reddish fluid, in which are found at times the parasite or its eggs.

History.—The history of the discovery of the parasite in the tiger and man has already been given (p. 366). Its connection with disease in man has been worked out by Suga, Baelz, Manson, Miura, Katsurada, and Musgrave, the last observer giving the most complete account of the disease up to date.

Climatology.—Paragonimiasis is found principally in China, Corea, Japan, Formosa, the Philippine Islands, and Sumatra.

Ætiology.—*Paragonimus westermani* occurs in the cat, the dog, and the pig, but how it infects man is quite unknown. The path of entry into the human body is believed to be through the alimentary canal in food or drink, and thence to different parts of the body by means of the lymphatics; but this has not been proved, and other routes are therefore by no means impossible. It appears to be more common in males than in females.

Pathology.—The pathology of the disease is by no means clear and how the various pathological changes are evolved is unknown.

Musgrave has classified the lesions into :

1. The non-suppurating lesion.
2. The tubercle-like lesion.
3. The suppurating lesion.
4. The ulcerative lesion—

(*a*) in the skin;
(*b*) in the bronchial mucosa;
(*c*) in the intestinal mucosa;
(*d*) in the bile-duct.

The simplest lesion appears to be an infiltration of the connective tissue of an organ with eggs, without any histological changes at first, but later with a proliferation of the connective tissue and the formation of a cirrhosis or a round-celled infiltration, with sometimes many eosinophiles, which may lead to abscess-formation, and finally to ulceration. The abscess-formation may at times produce caseous material, giving a tubercular appearance.

The non-suppurating lesion may therefore be simple infiltration of the tissue by eggs, with or without inflammation. On the other hand, cirrhotic changes may be seen, especially in the liver. In serous membranes an adhesive inflammation is often produced, associated with the presence of eggs in brown patches at the points of contact.

The inflammation of the organ may, however, proceed to pus-formation, resulting in a typical abscess. On the other hand, the tissues generally attempt to circumscribe this abscess by a fibrous wall, and thus produce what is called the typical lesion of the disease. In the centre of the abscess will be seen degenerated cells, blood, eggs, and perhaps a parasite. Then comes a capsular wall of fibrous connective tissue, smooth towards the centre, and joining the rest of the organ externally. Around this wall the connective-tissue of the organ is proliferating and congested. In this way the typical little cysts, with dull blue-grey walls, smooth internally, and containing a thick, reddish fluid, with or without eggs or a parasite, are formed. These lesions may work their way to a cutaneous or mucous surface, and so open into a bronchus, or into the intestine, or the bile-duct, or on to the skin, thus giving rise to ulcers in those regions. The intestinal ulcers closely resemble dysenteric ulcers, and, indeed, may become secondarily infected with amœbæ or bacteria.

In course of time these lesions may show some attempt at healing and scar-formation, but generally this is not very successful.

Morbid Anatomy.—The body may be well nourished, but more usually is emaciated and anæmic. Ulcers can be seen at times in the axillæ and groin, leading into diseased glands. The muscles may contain abscesses. The pleura, pericardium, peritoneum, and more rarely the meninges, show the chronic inflammations and the non-suppurative lesions mentioned above. The lesions found in the lungs are diffuse cirrhosis, bronchiectatic cavities, pneumonia, and caseous abscesses, while those of the liver are cirrhosis, perihepatitis, and abscess-formation. The typical lesions mentioned above may be found in the spleen, pancreas, small and large intestines, kidneys, bladder, epididymis, prostate, and in the choroid plexus of the brain.

Symptomatology.—As the invasion of the body is so generalized, the symptoms are very varied. Musgrave differentiates four varieties—the generalized, the thoracic, abdominal, and cerebral; but there is nothing very characteristic about any of these types.

In *the generalized type* there may be fever, enlarged lymphatic glands, general muscular pains, and ulceration of the skin.

In *the thoracic type* there will be cough, with the expectoration of purulent or, more generally, blood-stained sputum, in which the eggs may be best seen by the addition of a little 0·1 per cent. solution of sulphuric acid. More rarely an adult parasite appears in the sputum, which also may contain Charcot-Leyden and creatinin crystals. The patient generally complains of pain in some part of the chest. The physical signs may indicate bronchopneumonia or pleural effusion, which may be serous or purulent.

In *the abdominal form* of the disease there are only the vaguest symptoms of dull, aching pains and tenderness, while diarrhœa, appendicitis, epididymitis, or cirrhosis of the liver, may be demonstrated by the usual physical signs and symptoms. When diarrhœa occurs, the eggs may be found in the fæces.

The cerebral type is associated with epilepsy, which may be Jacksonian in character, while neuritis or paralysis may also be present.

The blood and urine have not yet been fully examined. Though generally chronic, the course may be acute if complicated by septic or other diseases.

Complications.—The most usual complications are tuberculosis and entamœbic dysentery.

Diagnosis.—With the above symptomatology, it will be obvious that the diagnosis depends entirely upon finding the eggs of the parasite in the sputum, the fæces, the scrapings from the ulcers, or the fluids obtained by puncture of a hydro- or pyothorax. Suspicions as to the presence of the disease will be strongest when cases showing any of the above signs occur in the endemic area.

Treatment.—The treatment must be devoted to relieving individual symptoms, but Musgrave recommends treatment by iodide of potash. Removal from the endemic area is, of course, indicated.

Prophylaxis.—Beyond general hygienic advice, it is impossible to indicate prophylactic measures, when so little is known about the life-history of the parasite.

KATAYAMA DISEASE.

Definition.—Katayama disease is caused by *Schistosomum japonicum* Katsurada 1904, and is characterized by diarrhœa and dysenteric symptoms, painful enlargement of the liver and spleen, with or without fever, dropsy, progressive anæmia, and sometimes pulmonary and brain symptoms.

History.—In 1887 Mazimi drew attention to a peculiar form of cirrhosis of the liver which was found in certain districts in Japan, and was caused by the ova of some unknown parasite. His discovery was confirmed, and the ova were found in other organs besides the liver; and the disease, which became well known among Japanese medical men, was named 'Katayama disease,' from a town in Bingo, one of the districts in which it is common. In 1904 Katsurada, who was resident in the infected area, discovered that the ova were those of a *Schistosomum*, and, further, found the adults in the portal vein of a cat. He therefore named the parasite *Schistosomum japonicum*. In the same year Fujinami discovered a female worm in a human being. Meanwhile Catto found the same parasite in a Chinaman from Fukien, and described it in 1905, and in the same year Stiles and Looss gave accounts of the disease. In 1906 Woolley, in a most excellent paper, described its occurrence in the Philippine Islands. Logan has found it in a Chinaman from Hunan, and in 1909 Peake recorded three cases from a small town on the Siang River, in the Hunan province of Central China.

Climatology.—It occurs in Japan and China: in the former in the provinces of Bingo, Yamanashi, Hiroshima, and Saga; while in the latter it is reported up to date from Hunan and Fukien.

Ætiology.—The cause of the disease is *Schistosomum japonicum*, which is probably introduced into the body, either through the skin or by the mouth, in water polluted by human fæcal matter. Several observers favour the idea of entry through the skin of the legs while standing in stagnant water, but nothing is definitely known.

Pathology.—By some observers the parasites are supposed to feed on the blood, and by others to produce toxins which cause the progressive anæmia. The eggs apparently are spread through the body by the blood-stream, and lodge as emboli in the organs, more especially in the alimentary canal and liver, where they give rise to a round-celled infiltration and connective-tissue formation resembling bilharziosis, and cause hæmorrhagic enteritis and cirrhosis of the liver and spleen.

Morbid Anatomy.—On opening the abdomen, signs of old peritonitis may be seen, the appendices epiploicæ being matted together, and at times there are also signs of old pelvic peritonitis. The liver is cirrhotic and less than its normal size, and its surface is studded by nodules, usually larger than those of alcoholic atrophic cirrhosis. Glisson's capsule is thickened, and shows much connective tissue, with round-celled infiltration, in which lie the ova of the worm.

The small and large intestines and appendix may be thickened, and their mucosa is swollen and hyperæmic, and shows patches of ulceration and necrosis, and, in addition, papillomata, resembling those of bilharziosis. The eggs may also be found in the mesentery and in the mesenteric glands, the wall of the gall-bladder, the pancreas, the walls of the mesenteric vessels, and the pylorus. The adult worms may be found in some of the veins of the portal system, especially at the bifurcations of the smaller mesenteric vessels.

In addition, the eggs may be found in fibrous and round-celled infiltrations in the lungs and in the brain. This infiltration often takes the form of nodules.

Symptomatology.—The disease usually begins with diarrhœa or dysenteric symptoms, with or without fever, and is recognized by the presence of the ova in the fæces. Associated with these symptoms are abdominal pains, enlargement and tenderness of the liver, the hypogastrium shrinking, and the epigastrium enlarging and giving rise to a characteristic abdominal appearance. At the same time the dysenteric symptoms cease, and an irregular chronic diarrhœa sets in, with motions containing much undigested food, and associated with dyspepsia.

In course of time the preliminary enlargement of the liver may cease, and the organ may begin to shrink, but in any case the spleen becomes tender and enlarges, ascites appears, and the patient becomes steadily weaker, more and more anæmic, emaciated, and incapable of mental or physical work. The average of three differential blood-counts by Peake is as follows: Polymorphonuclears, 56·5 per cent.; mononuclears, 13·2 per cent.; lymphocytes, 15·6 per cent.; eosinophiles, 14·1 per cent. Attacks of fever may occur nightly, otherwise the temperature may be subnormal. The vascular, respiratory, nervous, and urinary systems are usually normal. If, however, the ova affect the lungs, there may be signs of bronchitis, broncho-pneumonia, and fibrosis; and if the brain, those of Jacksonian epilepsy. In children the development is stunted. Death may result directly from the action of the parasite, or be due to some intercurrent disease.

Complications.—The infection is generally complicated by the presence of *Trichuris trichiura*, *Agchylostoma duodenale* or *Necator americanus*, and *Ascaris lumbricoides*. Dysentery is a complication which may occur and kill the patient.

Diagnosis.—The characteristic signs are chronic painful enlargement of the liver and spleen, associated with ascites and chronic irregular diarrhœa, and marked eosinophilia, but a definite diagnosis is to be effected by finding the ova in the fæces. These ova are large (0·1 by 0·07 millimetre), oval, non-operculated, non-spined, smooth, and transparent, with a double contour sometimes showing a *Miracidium*, and when kept in water for a short time give rise to a free-swimming ciliated *Miracidium*.

Prognosis.—The prognosis is very bad, as the parasite directly or indirectly leads to the death of the patient. The mortality is not known, but Katsurada met with between thirty to fifty-four cases every year for five years in the infected area in Japan, and saw three to five deaths per annum, which he considered directly due to the parasite—*i.e.*, a mortality of about 10 per cent.—but he thinks that the indirect mortality would raise the percentage considerably.

Treatment.—The only treatment that can be suggested is to follow the example of the treatment in bilharziosis and intestinal schistosomiasis, and administer *Filix mas* and treat the dysenteric or diarrhœal symptoms.

Prophylaxis.—Until the method of invasion of the parasite is known, not much can be said under this heading, except to avoid contaminated water in drinking and bathing—*i.e.*, to use boiled water in infected areas for both purposes.

POROCEPHALOSIS.

Definition.—Porocephalosis is the invasion of the body by the larvæ of *Porocephalus armillatus* Wyman 1848 and *P. moniliformis* Diesing 1836, which become encysted in the liver and lungs, and ultimately develop into nymphæ, which may, by their wanderings, cause inflammation of organs and serous membranes.

History.—*P. armillatus* was first found in man by Pruner in 1846, and has since been studied by Bilharz, Fenger, Aitken, Giard, Broden and Rodhain, Dutton and Todd, and ourselves. *P. moniliformis* has been met with in Asia by Salm, in Java.

Climatology.—*P. armillatus* is confined to Africa, being met with in negroes resident or who have resided therein. It has been reported from Egypt and various parts of the West Coast of Africa, but especially from the Congo.

With regard to *P. moniliformis*, it occurs in Java and the Philippine Islands. Welch described a peculiar parasite as occurring in the mucosa of the intestine of a man in India which he considered to be an *Echinorhynchus*, but which, judging from the drawing, might well be a *Porocephalus*.

Ætiology.—The adults of both *P. armillatus* and *P. moniliformis* live in the nasal cavities and lungs of pythons and snakes, and though the life-history is as yet unknown, it is quite possible that Sambon's suggestion that the ova pass into the drinking-water, and so to man, may be correct. It is possible that the eggs hatch in the alimentary canal, and that the larvæ then pass into the organs.

Pathology.—The larvæ are found lying coiled in cysts in the liver and lungs. In due course these larvæ become nymphæ, which leave the cysts and wander through the body, appearing in the lungs and bronchi, causing bronchitis and broncho-pneumonia; in the peritoneal cavity, causing peritonitis; in the bowels, causing irritation. Perhaps they leave the body by the fæces; perhaps, also, by the sputum; but in any case they cause serious illness in, and death of, the victim.

Morbid Anatomy.—In opening the abdomen, the nymphæ may be found quite free in the peritoneal cavity, and may crawl up the hands and arms of the pathologist. They may also be found in the lumen of the alimentary canal, in the mucosæ, and thickness of the wall of the bowel. The larvæ may be seen encysted in the liver and lungs.

In the cysts they lie in a curved position, with the ventral surface on the outer aspect of the curve. The lungs show signs of bronchitis and pneumonia, and the peritoneum is usually chronically inflamed, but not always.

Symptomatology.—Very little is known with regard to the symptomatology, as all the cases have so far been discovered accidentally post mortem. The symptoms are vague pains in the abdomen and chest, and fever, with occasionally signs of mild peritonitis, hepatitis, bronchitis, or lobular pneumonia.

Diagnosis.—Unless the parasites can be found in either sputum or fæces, the diagnosis is not possible.

Prognosis.—The disease is occasionally chronic. The prognosis is serious.

Treatment.—There is no known treatment.

Prophylaxis.—If the drinking-water is boiled or filtered, there ought to be no danger of infection.

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CHAPTER XXXV

THE FILARIASES

Synonyms—Definition—Filariasis caused by *Filaria bancrofti* Cobbold 1877—History—Climatology—Ætiology—Pathology—Clinical description—Filarial lymphangitis—Filarial orchitis and hydrocele—Lymphatic varix—Varicose lymphatic glands—Chylous effusions—Elephantiasis—Rarer affections—Filariasis caused by other Filaridæ—References.

Synonyms.—Filarial Disease, Filariose, Maladies filariennes, Filaria Krankheit, Filariasi.

Definition.—Filariasis is a term denoting the infection of man or animals by any species of *Filaria—e.g.*, *Filaria bancrofti* Cobbold 1877, *F. medinensis* Linnæus 1758, *F. loa* Guyot 1778, *F. volvulus* Leuckart 1893, and many others.

FILARIASIS CAUSED BY FILARIA BANCROFTI COBBOLD 1877.

The diseases produced in man by *F. bancrofti* Cobbold 1877 include lymphangitis, orchitis, varix in lymphatics and lymphatic glands, chylous extravasations, and elephantiasis.

History.—The appearance of the huge leg of elephantiasis is so striking that it was early noticed by ancient Indian writers, who give descriptions of diseases which clearly refer to elephantiasis of the leg and of the scrotum, and also less clearly to lymph scrotum. Further, they appear to have known that elephantiasis could affect the hands and other parts of the body.

The word 'elephantiasis' was first used by Celsus to indicate leprosy, and in this he was followed by most writers until Galen, who included true elephantiasis under the same term, an error which became firmly established as time passed. In the ninth and tenth centuries Rhazes and Avicenna, and other Arabian physicians, described true elephantiasis of the leg under the term 'da-fil' or 'dau-ool-fil,' or elephantine disease, which, however, only served to make the confusion between the two diseases more complete. In the seventeenth century Leonicenus and Varandæus pointed out that they were two distinct clinical entities, and in 1709 Clarke described elephantiasis on the Malabar coast of India, under the term 'Cochin leg.' In 1712 Kaempfer described endemic hydrocele, under the term 'andrum,' as occurring in India, and being associated with erysipelatous eruptions on the scrotum, which recurred at the time of the new moon. He also described a large foot under the term 'perical,' but his description agrees more with Madura-foot than with elephantiasis, though it is probable that he was confusing both diseases under the same term. In 1750 Hillary, a most careful and skilled observer, gave the first full and accurate account of the evolution of the large leg of elephantiasis, which he clearly differentiates from true leprosy, describing the successive attacks of fever, the lymphangitis and lymphadenitis, and the swelling of the limb, which, gradually becoming permanent and slowly increasing, produces the well-known condition.

He was ably supported in 1784 by Hendy, who, in a subsequent treatise in 1789, gave the first full account we have been able to trace of the development of elephantiasis of the scrotum, which he clearly recognized to be the same disease as that affecting the legs. He describes and figures an elephantiasis of the scrotum 24 inches in height and 6 feet in circumference at its base, and he further notes cases of spontaneous cure by sloughing. In 1809, and again in 1824, Alard wrote most excellent treatises on the elephantiasis of the Arabs.

In 1812 Chapotin was the first to describe hæmatochyluria in Mauritius, and he was followed by Salese in 1832, whose paper aroused so much interest in Brazil, where the disease had for long been well known, that in 1835 a conference on the subject was held in Rio de Janeiro, after which there were many investigations, among which may be mentioned those of Rayer in 1838, Quevenne in 1839, Sigaud in 1844, and Mozaé-Azema in 1858, the last-named observer reporting it in Réunion. In 1854 Jamsetjee described lymph scrotum. The result of all this work was to produce a consensus of opinion among Brazilian, French, and Indian physicians that hæmatochyluria and elephantiasis were merely different aspects of the same disease, and at the same time the classical researches of Danielssen and Boeck in 1848 on leprosy, and of V. Carter in 1860 on mycetoma, ended the confusion of these two diseases with elephantiasis.

In 1863 Demarquay, in Paris, discovered a *Microfilaria* in the fluid from a hydrocele in a person who had come from Havana, but this discovery passed unnoticed at the time. In 1866 Wucherer, stimulated by the discovery of *Schistosomum hæmatobium* in hæmaturia in Egypt, found a *Microfilaria* in the urine of a case of hæmaturia in Brazil, but at first thought it to be of no importance; but when, after two years of careful work, he regularly found the same small worm in the urine of persons suffering from hæmatochyluria, he published his discovery in 1868, in the same year in which Lewis independently found the same parasite in the urine of a case of chyluria in India. Lewis also found the same small worm in the blood and lymph of persons suffering from elephantiasis of the leg, and concluded that it was the cause of the chyluria and the elephantiasis. In 1876 Winckel found the same small parasite in the fluid from a case of chylous ascites.

In 1876-77 Bancroft discovered adult female worms in a lymphatic abscess in the arm, and in a hydrocele of the cord, and these worms were later described by Cobbold, who gave them the name *Filaria bancrofti*. About the same time Manson found the *Microfilariæ* in the lymph from the enlarged lymphatics of a lymph scrotum and from varicose lymphatic glands, and suspected that the so-called malarial orchitis must be of filarial origin. He also obtained a female worm from a case of elephantiasis of the scrotum, and in 1879 Lewis found pieces of male and female worms; while in 1888 Sibthorpe obtained perfect specimens of a male and female from a lymph scrotum, the former being described by Bourne. Lastly, in 1898 Maitland drew attention to the occurrence of synovitis in cases of filariasis, which he considered could not be looked upon as accidental, and must be considered to be of filarial origin, but this view cannot be considered to be proved.

In this way arose the knowledge that the causation of a form of lymphangitis, of lymphatic abscesses, of varices of lymphatics, and of lymph glands, of hæmatochyluria, of chylous extravasations, and of elephantiasis, was the invasion of the body by *Filaria bancrofti* Cobbold 1877.

In the meanwhile the epoch-making discovery of the agency of the mosquito in the dissemination of *Filaria bancrofti* was made by Manson in 1878, as well as the periodicity of the *Microfilariæ*, which only appear in the blood in large numbers at night, and in 1899 he discovered that they retire to the vessels of the lungs during the day. Low, Grassi, Noé and Fülleborn, have supplied the information as to the method by which the *Filaria* escapes from the mosquito and enters man during the act of biting. While, therefore, much has been done to elucidate the nature of the lesions due to the worm, researches are still required with regard to the method by which the worms produce the various pathological phenomena attributed to them, especially elephantiasis, and the rôle of a secondary bacterial infection in the production of the lymphangitis, abscesses, and elephantiasis.

The morbid anatomy has been investigated by but few observers, notably by Mackenzie, Manson, and Young.

Climatology.—The fact that ancient Indian writers were acquainted with elephantiasis of the leg and scrotum, while Celsus does not appear to have known the disease, and the further fact, mentioned by both Hillary and Hendy, that elephantiasis was rare in Barbadoes at the beginning of the eighteenth century, together with Hillary's views that the disease was introduced into that island by negro slaves from Africa, awaken suspicions that the endemic home of filariasis is Asia, and that it has spread from thence to Africa, and from Africa to America. If this gradual dissemination of filariasis is correct, it may explain many features of the epidemiology which are difficult at the present time to comprehend.

Be this as it may, filariasis is now widely distributed throughout the tropics and the subtropics, extending from 35° N. to 25° S. in the Eastern Hemisphere, and from 25° N. to 30° S. in the Western Hemisphere.

In Asia it is known in Arabia, India, Ceylon, Burma, Indo-China, China, and Japan. There was, however, some doubt concerning the Philippine Islands, for Ashburn and Craig, in their description of *Filaria philippinensis*, state that filariasis is rare in those islands, and that '*previous descriptions of filariæ observed in natives contain nothing which would exclude the possibility that the observers might have been dealing with F. philippinensis.*' They leave the reader with the impression that *F. philippinensis* is non-pathogenic, but they do not make any statement on the question of pathogenesis. Phelan and Nichols, however, found it once in a case of filariasis. Calvert reported cases of filariasis from Luzon, but Wherry and McDill say that chyluria and chylocele are rare, and elephantiasis is absent. Recently, however, Phelan and Nichols have demonstrated that filariasis is common in the Philippine Islands, and that *F. bancrofti* is the most commonly observed filaria.

It is known in Australasia, especially in Queensland, and in Oceania, especially in Samoa and the Friendly Islands, but is absent in the Sandwich Islands.

In America it occurs in the Southern United States, in Central America, the West Indies, in Guiana, Venezuela, Brazil, Peru, and Columbia.

In Africa it is common on the West Coast, in South Africa, East Africa, Madagascar, Réunion, Mauritius, and Egypt.

In Europe it is said to exist near Barcelona and in Turkey.

In these countries its distribution is unequal, being in general more common along sea-coasts and the banks of large rivers, but presenting peculiar circumscribed endemic areas. Thus, Daniels points out that in the Shiré Highlands filariasis and elephantiasis are only found in immigrants, while along the lower Shiré River both are common.

Still more interesting is his observation that at the southern end of Lake Nyassa there was only one case of filariasis met with, and none of elephantiasis, while at the northern extremity both were frequently seen.

The distribution must depend upon the presence or absence of mosquitoes capable of disseminating the worm, but this aspect of the epidemiology still requires a considerable amount of research; further, the distribution of the suitable mosquitoes must depend upon many factors concerning which we are quite ignorant. When these conditions are better understood, the climatology will be rendered more explicable.

Two atmospheric conditions—viz., high air-temperature and considerable atmospheric humidity—have long been known to be associated with the prevalence of filariasis and elephantiasis, and the reason of this has recently been explained by Fülleborn's experiments on the dog *Filaria*. This observer found, as the result of most careful experiments, that the *Filaria* developed better in mosquitoes if the air-temperature was high, and in that respect resembled the malarial parasite; and, further, that at high temperatures the *Filariæ* are able to leave the proboscis more easily, and to penetrate the skin more quickly than at a low temperature.

Further, the moisture in the air is of importance, as the *Filaria* passes from the proboscis on to the skin, and either makes its own way through this into the tissues, or enters the aperture of the mosquito's bite after it has withdrawn its stilettes, and, therefore, has to be some time in contact with the skin, which, if dry, will have a harmful effect upon it, but if moist, will not be injurious to it.

Ætiology.—The causation of the various pathological phenomena mentioned above is *F. bancrofti* Cobbold 1877, introduced into the body by the bite of a mosquito.

The known carriers of the worm, as given by Theobald, are *Culex fatigans* Wiedemann 1828, *Mansonia uniformis* Theobald 1901, *M. pseudotitillans* Theobald, *Pyretophorus costalis* Loew 1866, *Myzomia rossii* Giles 1899, *Myzorhynchus nigerrimus* Giles, *M. minutus* Theobald 1903, *Cellia albimana* Wiedemann 1821, while the worm is known to be capable of undergoing a part of its development in certain other mosquitoes already mentioned in Chapter XVI.

The reason of non-completion of full development in any and every mosquito is not known.

After development in the thoracic muscles of the mosquito the embryo passes into the labium, and when the mosquito bites it works its way through Dutton's membrane on to the skin, its passage being favoured, according to Fülleborn, by high air-temperatures and moist conditions of the skin. Arrived on the skin, it may work its own way into the body through the skin like an Agchylostome embryo ; or it may enter through the aperture of the mosquito-bite when the stilettes have been removed, for before this takes place it is impossible for it to pass through this aperture, which is completely filled by these appendages.

Its further history and wanderings in the body are quite unknown until the adult condition is reached. The adults (males and females) are generally found lying together, though the females appear to be in preponderant numbers in lymphatic vessels. Here the female produces the thin *Microfilariæ*, which pass through the lymphatic glands and thoracic duct into the blood-stream, in which they are found in large numbers at night, retiring in the day-time mostly to the bloodvessels of the lungs.

When taken into the mosquito's stomach they escape from their enclosing egg-shell, and, entering the thoracic muscles, complete the cycle of development.

It is interesting to note that in various parts of the tropics natives believe that elephantiasis and other filarial diseases may be transmitted through sexual intercourse.

The adults lying in the lymphatic vessels may mechanically cause obstruction to the flow of lymph, and thus produce varices, inflammation of vessels and glands, and if the varicose vessels rupture, extravasation of lymph or chyle.

While this ætiological relationship of the worm to the lymphangitis and lymphatic abscesses, to the varices in lymphatics and lymphatic glands, to hæmato-chyluria and chylous extravasations, is admitted by all observers, there are those who doubt this relationship with regard to elephantiasis. These authors base their objections upon the facts that the worm and its larvæ may be absent in well-developed cases, and that the disease can occur in countries in which filariasis is believed not to be present, both of which are quite true, but are capable of explanation. There is an undoubted general relationship between the number of cases of filariasis and of elephantiasis in a district. Where there is no filariasis, elephantiasis is either extremely rare or unknown ; where there is abundant filariasis, there are also many cases of elephantiasis.

In investigating this point in a locality care must be taken to exclude immigrant cases of both filariasis and elephantiasis. Thus, Low failed to find either condition in the inhabitants of the forests of British Guiana and in the Wagandas, natives of Uganda, though immigrant cases were met with.

The adult *Filaria* has been found in the tissues removed by operation from a case of elephantiasis of the scrotum ; and, further, the condition of elephantiasis is produced as a rule by a series of attacks of lymphangitis, which in every particular resemble undoubted filarial lymphangitis.

It is true that a secondary bacterial infection may possibly assist the development of the disease, for a diplococcus has been found by Dufougeré, which he calls the 'lymphococcus,' and his findings have been confirmed by Foulerton. Le Dantec describes a similar organism, which he calls the 'dermatococcus'; but the main cause of elephantiasis in the tropics is *Filaria bancrofti*, though it is quite possible that, exceptionally, other causes may lead to occlusion of lymphatics and the formation of elephantiasis.

Pathology.—If the parent-worms live in positions in which they do not obstruct the flow of the lymph, and if they are not accidentally injured, no pathological effects will be produced on the host; and our observations support Manson's theory that the presence of the worms may produce no ill-effect upon the host, for we know of a case where for years they have produced no symptoms.

But if the parent-worms obstruct the circulation of the lymph mechanically—for example, when three or four come together in an important main lymphatic trunk—then the retained lymph is certain by mechanical pressure to damage the tributary channels. Further, if any accidental injury is inflicted upon the female parent-worm, this may cause abortion, and as a result the production of oval eggs instead of elongated embryos, and these, as will be explained below, are liable to block up the small lymph channels of the skin or of a lymphatic gland. Therefore Low is quite correct in his statement that 'the *Filaria* is not entirely compatible with health,' for very slight causes will produce disease.

In certain districts from 5 to 15 per cent. of the population is infected with filariasis, and therefore if there are many mosquitoes capable of carrying the worm, there ought to be multiple infection of the individual host; and one would also assume that the heavier the infection, the greater the liability to obvious disease. Multiple infection would be more liable to occur in natives than in Europeans. As a matter of fact, heavy infections with the parent-worms have not yet been described, though it must be admitted that but few post-mortem examinations are on record; and, moreover, as Fülleborn has shown, it is at times by no means easy, even with the utmost care, to find the adult worms, though they may be found even in fair numbers after considerable search in those parts of the lymphatic system which appear to be least affected. When the case is one of varicose lymphatics, or lymphatic glands with clear lymph, the obstruction must be looked for below the junction of the lacteals with the receptaculum chyli, but when the fluid is milky, it is obvious that the obstruction must be beyond this point.

The cause of the obstruction may be a coiled-up mass of worms—*e.g.*, Young found six females and one male in such a bundle—and they may be discovered behind a valve or in a dilated sinus. A single female worm may, however, be found lying in a dilated lymphatic, the draining gland being probably blocked by the aborted ova. The irritation caused by the worms may lead to a permanent blocking of a main lymph channel, which will persist even after the irritating worms have died and disappeared, as has been observed by Mackenzie; or, again, the thoracic duct may be found dilated in part of its course, but quite patent throughout, though associated with enormous varicose glands and vessels and a complete absence of worms, which simply means that the parasites having caused the lesions have died and disappeared.

In chylous extravasations the blocking of the thoracic duct leads to engorgement of the renal, the lumbar, and the pelvic lymphatic channels with lymph, as well as that of engorgement and dilatation of the lacteal vessels themselves.

If the lymphatic vessels of the bladder or other parts of the urinary tract rupture as a consequence of this pressure, the result will be chyluria, and if, as often happens, some bloodvessels also rupture, there will be hæmato-chyluria. If the abdominal lymphatics rupture, there will be chylous ascites; if those of the tunica vaginalis, there will be chylocele.

If, on the other hand, the obstruction is posterior to the junction of the lacteals with the receptaculum chyli, then ordinary ascites, hydrocele, and varicose lymphatics of the scrotum (lymph scrotum), of the leg, and varicose groin glands, will result. More rarely the lymphatics of the arm may be affected in the same manner.

The lowered resistance of the tissues engorged with lymph renders them specially liable to inflammation, which may at times go on to abscess-formation, and which, if often repeated, will end in elephantiasis.

Manson believes that elephantiasis arises by a damage to the female worm, causing her to produce immature embryos, which lie coiled up in the egg-shell, instead of stretching it considerably. The immature egg is 50 μ in length by 34 μ in breadth, while the fully-developed *Microfilaria* is 130 to 300 μ in length by 7 to 11 μ in breadth; therefore it is not difficult to imagine that a lymphatic, along which the slim *Microfilaria* passes with ease, might be quite blocked by the immature egg, and that if sufficient channels in the skin or in the lymphatic glands were blocked, lymph stasis would occur, and, as a result, the connective tissues would inflame and increase in amount, which, together with the excess of lymph, would increase the size of the part.

Manson bases this theory on his observation of eggs escaping from the ruptured vesicles of a lymph scrotum.

It is believed that the smooth elephantiasis (elephantiasis glabra), in which the skin is smooth, is due to blocking of the channels in the groin glands, and rough elephantiasis (elephantiasis verrucosa), in which the skin is very nodular, is due to blocking of the small skin capillaries, but we are not acquainted with definite proofs of this theory.

The Blood.—The blood in filariasis does not exhibit anæmia unless there is hæmato-chyluria or diarrhœa; the number of leucocytes is normal, though it is said that at first there may be leucocytosis. The eosinophiles are at times increased.

Morbid Anatomy.—The morbid anatomy naturally varies with the variety of the pathological lesion produced.

In lymphangitis the lymphatic vessels will be found enlarged and inflamed, and abscesses of varying size may at times be found containing the dead worms.

In lymphatic varix or varicose lymphatic glands the obvious lesions may, and generally do, form part of a much larger dilatation of the pelvic and lumbar lymph vessels and glands. The vessels are found enormously dilated with thickened walls, while the glands are riddled with dilated channels. At first the appearance of the gland may not be much altered, and on section it may show the appearance of a sieve riddled with holes, but in more advanced cases all appearance of a lymphatic gland disappears, and it is transformed into a large sac divided by fibrous tissue, septated into numerous compartments.

In chylous extravasations the thoracic duct may or may not be found impervious, but in any case the lacteals, the lumbar, pelvic, pudendal, and crural lymph vessels will be found enormously dilated, and the lumbar lymph glands converted into septated sacs. The site of the ruptured lymphatics is, however, by no means easy to find.

In elephantiasis the lymphatic vessels will be found dilated and thickened, and in early cases a round-celled infiltration may be seen in the connective tissue of the part; but in later cases this has led to a hypertrophy of the connective tissues of the skin and the fasciæ, including those around the muscles, the vessels, and nerves, while all the tissues are sodden with retained lymph. The muscles of the affected regions are found to be in a state of fatty degeneration; the bones may be thickened and covered with osteophytes, or more rarely atrophied, and still more rarely invaded by caseous abscesses.

Microscopically the epidermis may be normal or thickened, with atrophied or elongated papillæ; the sweat glands and hair-follicles may or may not be degenerate.

In cutting into the tissue of a region affected with elephantiasis the skin may be noted to be thickened, and below it there will be found dense fibrous trabeculæ, with the spaces filled with yellow, oily, fatty substance, which exudes lymph, while the vessels and nerves will be found much increased in size.

The Clinical Description.—The clinical description of the various lesions will be arranged under the headings Filarial Lymphangitis, Orchitis, Lymphatic Varix, Varicose Lymphatic Glands, Chylous Effusions, and Elephantiasis of various parts of the body—*e.g.*, scrotum, leg, etc.—and, finally, a few remarks will be made with regard to rarer lesions.

FILARIAL LYMPHANGITIS.

Synonym.—Elephantoid fever.

Definition.—Filarial lymphangitis is an inflammation of lymphatic vessels in any part of the body caused by *Filaria bancrofti.*

Remarks.—Attacks of lymphangitis, associated with an erysipelatous eruption of the skin, are extremely common in the tropics, and are often of a filarial nature, and by their repeated recurrences produce elephantiasis.

Symptomatology.—The attack often begins with a shivering fit, and a rise of temperature to any degree from 101° F. to 104° F., with vomiting and headache. In some cases there is no pain in the affected area, but a careful examination, or the sensation of pain on the part of the patient, will lead to the discovery of a red œdematous area of skin, from which the inflamed lymphatic may be noted extending towards the nearest lymphatic glands, which may or may not be inflamed and painful. Usually the temperature falls quickly in a couple of days to normal, and does not rise again, though it may be several days before the erysipelatous rash disappears and the lymphatics return to normal.

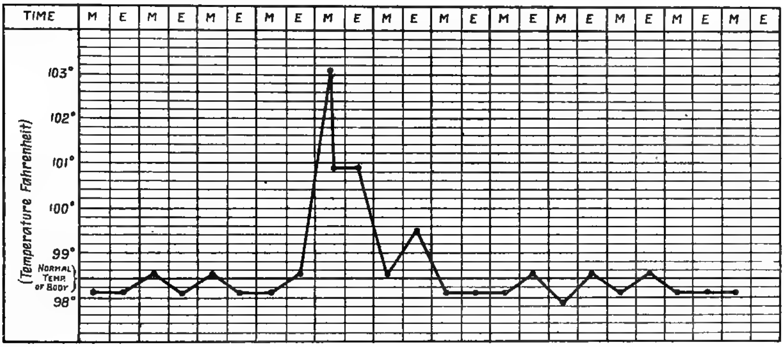

FIG. 305.—TEMPERATURE-CHART OF A CASE OF ELEPHANTIASIS OF THE LEG DURING AN ATTACK OF FILARIAL FEVER.

Complications.—Rarely does this condition go on to abscess, which may be caused by a dead filarial worm or a secondary infection.

Sequelæ.—Sometimes, after the acute inflammation has subsided, a lymphatic can be felt as a hardened cord, which, if excised, will be found to contain adult *Filariæ.*

Diagnosis.—The only condition which could reasonably be mistaken for this affection is a caterpillar sting, which closely resembles it in all details. The history of the case will indicate the correct diagnosis.

Treatment.—The treatment consists of rest in bed, a mild purgative, and a little phenacetin and caffeine to relieve the headache, while some of the old authors advise arsenic or tincture ferri perchloridi, ♏ x.-xx., given three times a day, well diluted. Locally, at first lead and opium lotion, and later an ointment, composed of ichthyol and lanoline, gives relief. If an abscess forms, it must be evacuated and treated on ordinary principles.

FILARIAL ORCHITIS AND HYDROCELE.

This complaint begins with pains in the testicle, fever, and at times rigors, pain in the back and lower part of the abdomen and groins. The testicle enlarges, and is tender and painful, while an effusion forms in the tunica vaginalis of either lymph or chyle. The lymph thrown out is at first inflammatory, and may coagulate, and is usually absorbed after the fever subsides, but may persist and form a filarial hydrocele. The effusion of chyle is, however, more usually permanent, and forms one of the varieties of chylocele, to be mentioned later.

Treatment.—The treatment consists of rest in bed and the application of lead and opium lotion, and cool applications, together with fairly vigorous purgation of the bowels.

FILARIAL LYMPHANGIECTASIS.

Synonyms.—Lymphatic Varix, Lymph Scrotum.

Definition.—Filarial lymphangiectasis is the dilatation of lymph vessels brought about by obstruction to the flow of lymph, due to the presence of *Filaria bancrofti*.

Remarks.—Filarial lymphangiectasis can, of course, take place in any part of the body, but the most common situations are in the scrotum, where it is called 'lymph scrotum,' in the spermatic cord, in the leg, and in the arm.

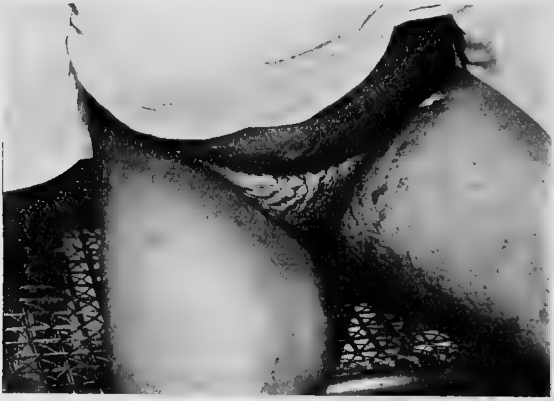

FIG. 306.—LYMPHANGIECTASIS.

Symptomatology.—In the scrotum the affection begins with an attack of fever, associated with redness, swelling, and pain in that region. When the fever has subsided, the whole scrotum is found swollen and elastic. It may be smooth or rugose, and on inspection the skin shows a number of small clear vesicles, which, if ruptured, discharge either lymph or chyle containing filarial embryos, or, much more rarely, eggs.

If the vesicles are ruptured, the discharge of lymph may be quite considerable in the twenty-four hours, and may produce such marked exhaustion in the patient as to necessitate an operation.

In the spermatic cord the disease begins with pain and swelling in the testicle, cord, and lower part of the abdomen, associated at times with fever. When the acute symptoms have subsided, a swelling like a varicocele, which disappears in the prone position and reappears when standing erect, will be noticed along the cord, but the vessels constituting the swelling will be noted to be softer, less tortuous, and more like a series of pouches than a true varicocele.

In lymphangitis of the leg there is the same fever, with swelling of the glands, leaving a soft swelling in the groin, which disappears on lying down and reappears on standing up, and which has no impulse on coughing.

Treatment.—As the local condition is simply part of a much more generalized varicosity of the lymphatic vessels, it is best to treat it symptomatically with antiseptic dusting-powders, such as boracic acid, zinc oxide, and dermatol, etc.

If, however, lymphorrhagia is taking place and the patient is becoming exhausted, it is necessary to remove some of the diseased tissue and to ligate the dilated vessels, but in so doing it is as well to warn the patient that this will not cure the disease, and, indeed, may be followed by elephantiasis or even chyluria.

VARICOSE LYMPHATIC GLANDS.

Synonyms.—Helminthoma Elastica, Adenolymphocèles.

Definition.—Varicose lymphatic glands are glands enlarged, sometimes to an enormous extent, by dilatation of their lymph paths, brought about by obstruction to the flow of lymph.

Remarks.—The glands most commonly found enlarged in patients are the groin glands, less frequently those of the axillæ, while even the parotid lymphatic gland has been recorded to have been affected. In post-mortems, as already noted, the lumbar glands may be found converted into septated sacs.

Symptomatology.—The glands enlarge after attacks of fever, and are usually found as soft, elastic swellings, which are easily movable when small, and are covered with normal skin. They are found in the groin, inguinal or femoral regions, and in the axilla. If punctured with a hypodermic needle, lymph or chyle can be obtained at times containing *Microfilariæ*. Usually small, they may assume enormous proportions, reaching below the knee, and seriously impeding locomotion.

Treatment.—They may be removed if necessary, but this should not be done without due cause, as they are only part of a more widespread disorder. Radium treatment has recently been advised by Sir Havelock Charles.

FILARIAL CHYLOUS EXTRAVASATIONS.

Chylous extravasations are due to the rupture of dilated lymph or lacteal vessels into the urinary passages, the bowel, the tunica vaginalis, or peritoneum.

They may, therefore, be considered under the headings of Hæmato-chyluria, Chylous Diarrhœa, Chylocele, Chylous Ascites.

Hæmato-Chyluria.

Definition.—Hæmato-chyluria is the passage of blood and chyle, or chyle only, with the urine, and is due to the rupture of dilated chyle-containing lymphatic vessels.

Symptomatology.—The onset of the attack is usually abrupt, without marked symptoms, though vague pains may be felt, and at times there may be fever, pains in back, perinæum, and thighs. Usually, however, the patient simply asks advice because he is passing milky or bloody urine.

As a rule the urine clears in the course of time, but it is merely an intermission, and the symptoms will in due course recur, and intermissions and attacks will follow each other for years; on the other hand, however, it may be continuous, and not intermittent. The duration of the intermissions may be days, months, or years, while the attacks may be attributed to exertion or emotion. After continuing for some time it may lead to exhaustion, neuralgic pains in different parts of the body, disordered bowels, coated tongue, and dry, harsh skin, all of which are symptoms of a cachexia.

If the urine clots in the bladder there may be severe pain and strangury. The urine generally presents the appearance of milk, but may be pinkish in colour from admixture with blood, and may clot. It is usually passed in fair quantity, and it will be noticed that the morning urine is usually very clear, while that at night is much more milky or red. On standing, the fat accumulates on the surface, giving rise to a cream-like appearance. Under the microscope, as a rule, no fatty globules, however minute, are observed, but white and red corpuscles, and at times *Microfilariæ*, may be seen. Because of the presence of fat the specific gravity is low, varying from 1015 to 1020. The reaction is usually acid. On shaking the urine with ether, the fat can be removed and estimated, when it will be found to vary from 0·6 to 3·3 per cent. After the removal of the fat, the urine can be tested for albumin, which is always present, and which usually persists for some time after the fat has disappeared. The quantity of albumin varies from 0·6 to 0·9 per cent. Albumoses and sugars are absent.

Treatment.—The treatment is purely symptomatic, and consists of rest in bed, lying as much as possible in the prone position, while in some cases methylene blue may be given in 2-grain doses, together with salol or urotropine. The diet must be bland, non-irritating. Astringent injections into the bladder have been used, and gallic acid, nitrate of silver, acetate of lead, iodide of potassium, and thymol have been administered internally, but have not been found to be efficacious. Exposure to X-rays has been recommended.

If the urine clots in the bladder, it must be washed out under chloroform by means of an aspirator, and if this is not successful the bladder may have to be opened and drained.

Chylous Diarrhœa.

Diarrhœa with chyle and blood in the motions has been recorded, but is rare.

Chylocele.

This may develop gradually, the tunica vaginalis filling up with an opaque fluid, which on tapping is found to be chylous, and may contain *Microfilariæ*. It may, however, be preceded by an attack of fever and orchitis. It is said that the sac is less tense in the morning, and more so at night.

Treatment.—A chylocele does not grow to any large size, and only requires occasionally to be tapped.

Chylous Ascites.

Chylous ascites is rarely met with in human beings, though we have seen two cases. It is common in animals as the result of filarial infection.

ELEPHANTIASIS.

Synonyms.—Elephant Leg, Cochin Leg, Barbadoes Leg, Galle Leg, Glandular Disease of Barbadoes, Elephantiasis Arabum, Da-Fil, Dau-ool-Fil, Pes Febricitans, Perical, Phlegmasia Malabarica, Elephantiasis Indica, Bucnemia Tropica, Morbus Elephas, Spargosis Fibroareolaris, Pachydermia, Hernia Carnosa, Elephantiasis Tuberosa et Scrotalis, Hypersarcosis, Mal de Cayanne, Sarcocèle d'Égypte, Roosbeen von Surinam, Shlipada, Kosharriddki, Barawa (Sinhalese).

Definition.—Elephantiasis is a chronic inflammatory hypertrophy of the fibrous connective tissue of a region of the body induced by lymph stasis, and resulting in a considerable hypertrophy of the skin and subcutaneous tissues.

Varieties.—The most common varieties of elephantiasis are the affection of the leg, scrotum, vulva, arm, and breast, while other regions are much more rarely affected. The different varieties must now be briefly described.

Elephantiasis of the Leg.

During attacks of filarial lymphangitis of the leg it is noticed that the limb becomes swollen, and though after the first attack it may resume its normal size, this does not happen after repeated successive attacks, and gradually the limb becomes more and more swollen, while the natural folds, especially the ankle fold, become much exaggerated by the swelling on either side, so that deep sulci are formed. The dorsum of the foot becomes swollen and puffy, and is separated by the deep ankle sulcus from the swollen lower part of the leg. In these sulci the débris of the cast-off epithelium, together with the excretions of the skin, accumulate and give rise to a foul-smelling discharge, and ulcers may form. At first the skin is smooth and soft, forming the smooth variety of the complaint, which may persist, or it may become dark, hard, thick, and rough, being elevated into bosses or warty elevations, forming the verrucose variety. The appendages now atrophy from malnutrition, the hairs may drop off, and the nails become rough and thickened, while the skin perspires less, and the sensibility is diminished. Ulcers may now form on almost any part of the foot. The swelling is more commonly met with below the knee, but the whole thigh may become implicated.

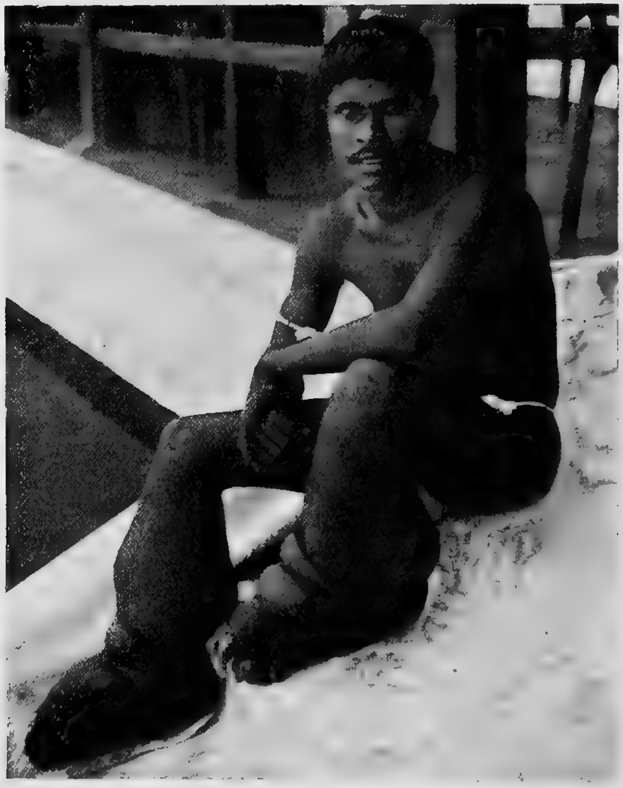

FIG. 307.—ELEPHANTIASIS OF THE LEGS.

If left untreated, the size of the leg gradually increases with repeated attacks of fever, and may reach considerable dimensions. After some years the attacks of fever may cease altogether, though the condition of the leg usually remains unchanged. In some rare cases elephantiasis may develop without the patient ever having an attack of fever.

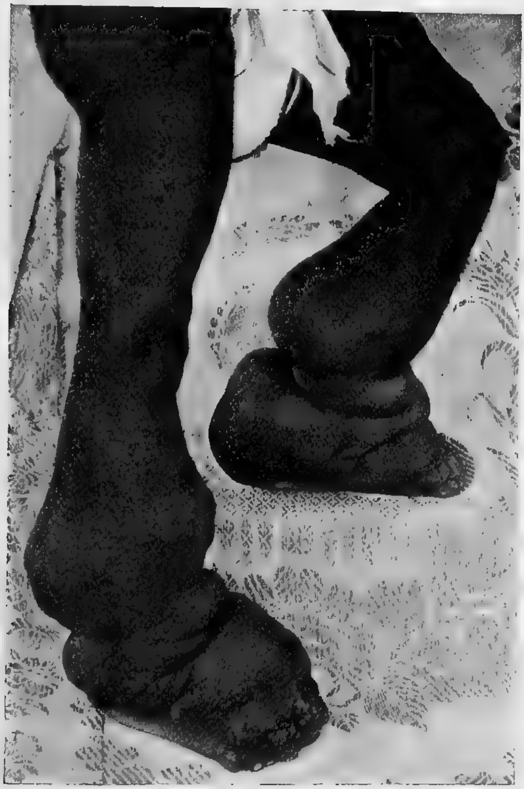

FIG. 308.—ELEPHANTIASIS OF THE LEGS.

Treatment.—A radical method of treatment has yet to be found. Of the various palliative ones the most satisfactory is perhaps that introduced by Castellani, which consists in keeping the patient at complete rest in bed, with thiosinnamin or fibrolysin injections and methodical bandaging. The details of the treatment are as follows: The patient is kept in bed and an injection of 2 to 4 c.c. of fibrolysin Merk (which consists of thiosinnamin and salicylic acid dissolved in water) is given daily for three to six months, the injections being interrupted for a few days from time to time. The injections may be made in the affected parts, or deeply into the gluteal region, where they cause much less pain. After each injection the whole limb is tightly bandaged with flannel bandages, which are kept in place day and night. In some cases rubber bandages may be used with great advantage, especially in cases of verrucose elephantiasis, because they render the skin much smoother. Unfortunately, many patients cannot stand rubber bandaging. To increase the pressure on the hardest parts pads of inelastic material may be applied before bandaging, and for this purpose small cylindrical gauze bags filled with ordinary small lead shot are found especially useful. In some cases massage of the whole limb before bandaging is useful. It is of the utmost importance that the pressure on the whole limb should be well distributed, otherwise the parts on which insufficient pressure has been made will be found to become swollen. It is also useful to keep the affected limb continually elevated by means of pillows, etc. In cases of verrucose elephantiasis in which the skin is covered with numerous horny masses, a spirit lotion of resorcin and salicylic acid (ac. salicylici, resorcin, āā gr. xxx.; sp. rect., ℥iv.) is useful in removing these horny masses. In successful cases after three to six months of this treatment the affected parts are of much smaller size, the skin is smoother, more elastic, and can be pinched into folds. Long elliptical strips of the

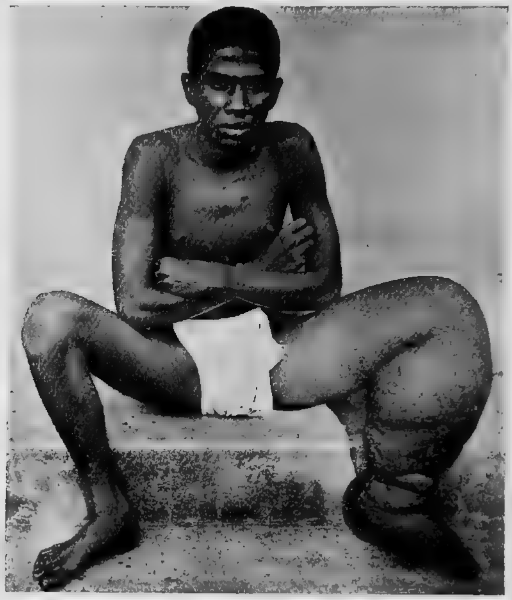

FIG. 309.—ELEPHANTIASIS OF THE LEG: BEFORE TREATMENT.

redundant skin and subcutaneous tissue may then be removed, the margins of the wound being stitched together. This would not be practicable before the medical treatment, as the skin being enormously thickened and inelastic, the coaptation of the opposed surfaces could not be obtained.

In our experience this treatment has generally only a slight and temporary effect in recent cases when the disease is in the acute stage with frequent attacks of filarial fever. On the other hand, the treatment gives much better and more lasting results in old-standing cases, especially in those of the verrucose type, characterized by the enormous neoformation of fibrous tissue and absence of fever. After treatment the patient should wear puttees or elastic stockings, and the rubber bandage should be applied from time to time.

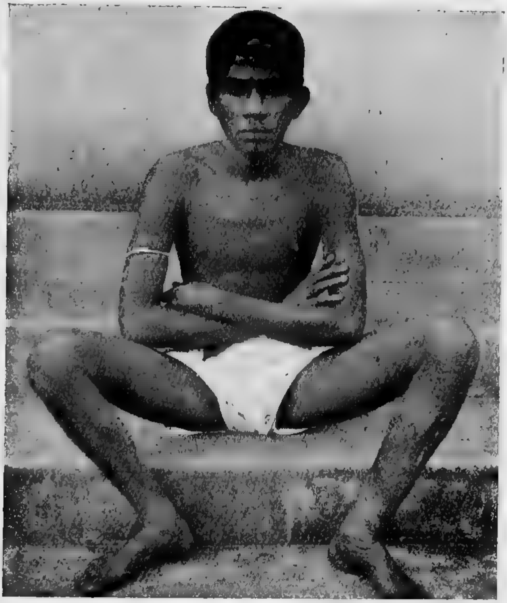

FIG. 310.—THE SAME CASE AS IN FIG. 309: AFTER TREATMENT BY FIBROLYSIN AND BANDAGING, AND WITHOUT ANY OPERATIVE MEASURES.

Recently Handley has treated cases by first preparing a vaccine from the diplococcus which he found in the blood, and administering this until the blood and lymph become sterile, and then performing his operation of 'lymphangioplasty' by silk introduced by means of long probes, which are pushed along the subcutaneous tissues, through small incisions, until a path is made from the affected region to one with a normal lymph circulation. In the one case so far reported there was marked improvement as early as eighteen days after the operation. Possibly a combination of Castellani's method of treatment with Handley's lymphangioplasty will give good results.

Other methods of treatment consist in bandaging, massage, tapping with Southey tubes, and even amputation, but none of these are satisfactory.

Elephantiasis of the Scrotum.

The disease may begin as a lymph scrotum, or with recurring erysipelatous attacks, with a red inflammatory blush on the skin, and fever. After each attack the scrotum is larger than it was before, and it goes on growing, if left alone, until it may reach the weight of 224 pounds, as mentioned by Chevers, which is probably the largest ever described. When well developed it forms a triangular-shaped mass hanging down between the legs, with the base downwards, and the apex upwards towards the pubes. On its anterior and upper aspect there is an aperture which leads into a canal, formed by the inverted prepuce, at the bottom of which is the glans penis. The penis itself is buried in the tumour. The testicles are situated at the upper and back part of the tumour, and are usually surrounded by hydroceles.

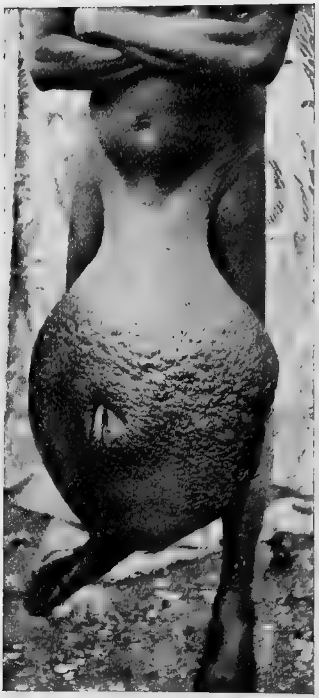

FIG. 311.—ELEPHANTIASIS OF THE SCROTUM.

If large, the base of the tumour is frequently ulcerated.

Treatment.—The treatment is removal, which is a very easy operation, and very successful. Manson says that the mortality need not exceed 5 per cent.

The most important feature of the whole operation is to have the skin perfectly clean and aseptic, and to carefully choose the parts of the skin which are to be used as flaps.

An elastic tourniquet in a figure of eight is applied round the pelvis and the neck of the tumour. The skin flaps are now marked out and deepened, the vessels being carefully ligatured as they are exposed.

The testicles are then dissected by perpendicular cuts, and the penis is set free by dissection, after cutting down the canal already mentioned as formed by the prepuce. This is best done with a pair of scissors.

The general mass of elephantoid tissue is now cut away gradually, ligaturing the vessels as the cutting proceeds, a process which prevents the omission of a vessel. The tourniquet is now loosened, and any bleeding spot secured.

If there are hydroceles present, these are opened, and the sac turned inside out, and after any redundancy has been removed, it is stitched around the testicle in the inverted condition. The flaps are now brought together and stitched over the testes, a drain of some description being introduced at the lower portion of the wound if this is considered to be necessary. Skin flaps should, if possible, be made for the penis; failing this, the raw area must be covered with protective, and allowed to granulate. The whole wound must now be antiseptically dressed, and usually heals without difficulty.

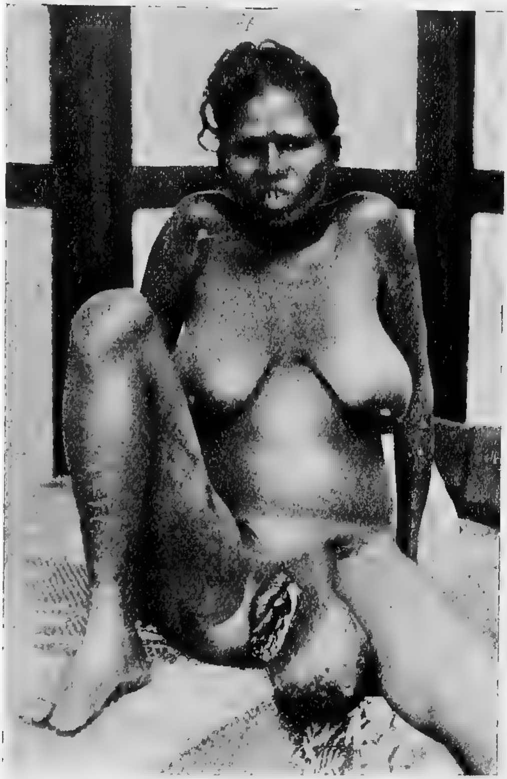

FIG. 312.—ELEPHANTIASIS OF THE LABIUM.

Elephantiasis of the Vulva.

This arises in the same manner as elephantiasis of the scrotum, and may affect the labia majora or the clitoris. It is, however, very rare. The tumour, according to Manson, may weigh 8 to 10 pounds, or more. The treatment is removal.

Elephantiasis of the Breast.

Elephantiasis of the breast is very rare, but can occur, and the enlarged breast may reach to the pubes or the knee. It may affect one or both breasts.

Elephantiasis of the Arm.

This is rare, but may arise in the same manner as in the leg. One arm or both arms may be affected.

Elephantiasis of the Scalp.

Rarely the whole scalp is enomrously thickened, and presents deep furrows.

Circumscribed Elephantiasis.

Large pendulous tumours of filarial origin, one to several, may be found.

RARER AFFECTIONS.

Lewis has recorded a case of filariasis in which chyle containing *Microfilariæ* was discharged from both conjunctivæ, while Maitland has described cases of acute synovitis of the knee as being of too frequent occurrence to be looked upon as merely coincidences.

FILARIASIS CAUSED BY OTHER FILARIIDÆ.

The lesions produced by *Filaria medinensis* Linnæus 1758, *F. loa* Guyot 1778, and *F. volvulus* Leuckart 1893, are described in Chapters LI. and LII., while the life cycles of non-pathogenic Filariidæ, such as *F. perstans*, *Microfilaria philippinensis*, and the less-known Filariidæ are described in Chapter XVI. It will be remembered that *F. immitis* Leidy 1856 does not occur in man, the supposed case being wrongly quoted.

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CHAPTER XXXVI

LEPROSY

Synonyms—Definition—History—Climatology—Ætiology—Symptomatology —Diagnosis—Prognosis—Treatment—Prophylaxis—References.

Synonyms.—Elephantiasis Græcorum, La Lèpre (French), Aussatz (German), Lebbra (Italian), Spedalskhed (Norwegian).

Definition.—Leprosy is a chronic general disease, caused by the *Bacillus lepræ* Hansen, which produces characteristic lesions in the skin, mucosæ, and nerves. The method of infection is unknown.

History.—Even at the present time there is occasionally much difficulty with regard to the diagnosis of leprosy from allied diseases, and therefore in ancient times and in the Middle Ages syphilis and skin diseases without doubt were confused with it. Hence the history is not easy to write. Nevertheless, such a repulsive and striking disease must have been noticed by the ancients, and therefore it is possible that the references in the Ebers Papyrus, and in the English Bible, the Rîg Veda, and ancient Japanese books, actually refer to what we call leprosy, together with other diseases. If this is so, leprosy is indeed ancient and widespread. It is probable that it passed from Egypt to Greece, and later to Italy, by means of Pompey's troops, and that it was disseminated throughout Europe by the Roman legions, by traders, and perhaps by the Crusaders returning from the East. In any case, leprosy gradually increased in Europe from the days of Pompey till, in the thirteenth century, it existed to such an extent as to move Church and State alike to combat its ravages. Stern measures were enforced, and the lepers were isolated in lazarettos. They were compelled to wear a special dress, to use a clapper when passing along the roads, to only indicate with a stick the articles they desired to buy in a market; while they were forbidden to drink from public fountains, to touch children, to speak to a healthy person in a loud voice, or to eat with any person other than a leper. Further, the Church performed the Burial Service over a person who was diagnosed to be a leper, and therefore officially he was dead. The result of this appears to have been beneficial, as the number of the lepers diminished rapidly in the fourteenth and fifteenth centuries, since when the disease has almost disappeared from many parts of Europe.

But while the disease was abating in Europe, it appears to have been introduced into Madeira and the Canary Islands about the end of the fifteenth century, and perhaps also into America by the Spaniards. The infection of the West Indies would appear, however, to have been mainly due to the negro slaves brought from Africa about the middle of the sixteenth century, after which the disease became common. There is great doubt as to whether it did not exist in South America in ancient times, but no clear evidence is forthcoming at present.

In India, Japan, and probably China, the disease is most ancient, while it is very common in South China. During recent years the Chinese have been moving about the world, and are accredited with introducing the disease into Kamschatka, the Sandwich Islands, Polynesia, Columbia, California, Australia, New Zealand, and also into Indo-China.

Though very common in North and Tropical Africa, it appears to have been unknown in South Africa until introduced in 1756 by the Dutch from Java, who carried it through Cape Colony and the Orange Free State into the Transvaal. It must, however, be stated that some people think it has existed for a long time in South Africa.

It is said that the numbers of lepers have markedly increased in South Africa since the advent of the East Indian troops in the middle of last century.

As regards medical literature, Hippocrates says but little about the disease, and perhaps really refers to psoriasis, while Aristotle defines it better. It is not, however, until the first century that Aretæus of Cappadocia gives a clear description of the disease, and not till 1847 that the first modern clinical account by Danielssen and Boeck appeared. The pathology of the disease has been carefully studied by Virchow, Vandyke Carter, Leloir, Babès, Unna, Zambaco, Innes, Campana, and Bergmann. In 1871 Hansen discovered the bacillus associated with leprous lesions, which has subsequently been studied by Neisser in 1879, and many others.

Many attempts have been made to cultivate this bacillus, notably by the Indian Commission, Van Houten and Rost, but though at the time thought to be successful, they have not been confirmed. In 1903 Dean and Stephansky, and later Rabinowitsch and Tidswell, discovered a peculiar leprosy-like disease in rats, the lesions of which contain bacilli closely resembling Hansen's bacillus in appearance, and not capable of cultivation. A diphtheroid bacillus has, however, been cultivated by Dean from two cases, and is said by him to be capable of being agglutinated by human leprous serum. There is probably no connection between the human and the rat disease.

The method of infection is at present unknown, though there are various theories, more or less ably defended, which will be mentioned later. The condition of the eye has been much neglected until recent years, when the researches begun by Bull and Hansen as far back as 1873 have been extended by Grossman in 1906, De Silva in 1907, but most importantly by Borthen in 1899.

Climatology.—At the present time there is but little leprosy in many parts of Europe, but it is still common in Iceland, while it is found in Spain, Italy, the Balkans, Turkey, Crete, and Cyprus. It is less frequent than formerly in Norway, Sweden, Greece, and some of the Mediterranean islands, rare in France and Germany, and almost extinct in Denmark, Belgium, Holland, Austria-Hungary, and England.

It is very common throughout the whole of Asia. In Ceylon there are numerous lepers, many of whom are treated in a leper asylum at Hendela, near Colombo, which is believed to be one of the best in the world.

In Australia the disease is known principally in Queensland and New South Wales, and also in Victoria; while in New Zealand it is known among the Maoris. It occurs in New Caledonia, Tahiti, and the Sandwich Islands.

It is spread sporadically over the United States, but is rare in Canada, while it is well known in Mexico and Central America, and common in the West Indies. In South America it appears to be far from rare in Colombia, Venezuela, the Guianas, and Brazil, but whether it is rare or not recognized in other countries is not known.

It appears to be spread all through Africa, but is certainly rare in West Africa, more common in Central and East Africa, and decidedly more common in North and in South Africa, where there is the celebrated Robbin Island Leper Asylum. There are people who believe Egypt to be the original home of the disease, from whence it spread to Asia and Europe.

Ætiology.—The disease is caused by Hansen's bacillus, which morphologically has the greatest resemblance to the tubercular bacillus, and is stained by the same methods. Recently, however, Jamanioto has described a silver nitrate method by which the tubercular bacilli are stained black, while the leprosy bacilli remain transparent. Cultivation has so far failed, though Clegg has reported cultivation in association with amœbæ.

The bacilli, which, as will be shown later, exist practically all over the body wherever diseased tissue is found, leave it by the nasal secretion, the tears, the salivary secretion, the sputum, the milk, the semen, urethral and vaginal secretions, and by the fæces, and are cast off with the scales of skin or the discharge of disintegrating tubercles. Of all these, the secretion of the nose appears to be of great importance, for, as Sticker and Van Houten showed, the bacilli are very commonly met with in that situation. The bacilli are reported to have been found in *Culex pungens* and *Cimex lectularius* by Goodhue, of the Molokai Leper Settlement. Finally, it may be stated that, notwithstanding one or two observations, the bacillus has never been found in earth, dust, air, water, or food.

With regard to inoculations into animals, experiments have been negative in rabbits, guinea-pigs, dogs, cats, bats, pigs, and birds, even though some experiments were thought at the time to be successful. Nicolle produced a hard indolent swelling with a few lepra bacilli by injection of leprous tissue in a *Macacus* monkey: Marchoux and Bourret have made inoculation experiments in a chimpanzee with partial success. In rats a peculiar skin disease, somewhat resembling leprosy, occurs spontaneously, as observed by Dean and Rabinowitsch.

With regard to the experimental inoculation of human beings, the only case cited as successful is Arning's inoculation of a Sandwich Island criminal in the arm with a leprous tubercle. This man developed a neuritis of the ulnar and median nerves four weeks after the inoculation, a tubercle five months later, the full signs of leprosy two and a half years later, and died a leper six years after the inoculation. It is, however, to be noted that he lived in a leprous country, and that there was leprosy in his family—facts which decrease the importance of the experiment.

There can, however, be no real doubt that the disease is in some way spread from human being to human being. In support of this there are many well-known facts—*e.g.*, the case reported by Benson, where an Irishman, having acquired leprosy in the West Indies, returned to Ireland, and died from the effects of the disease in about eleven months. During this period his brother not merely lived with him, but slept in the same bed, and, after his death, wore his clothes. In about four to five years this brother showed all the typical signs of tubercular leprosy, though he had only once been out of Ireland, and then only to visit England. Another similar case may be quoted of a person who, acquiring leprosy in Tonkin, returned to Strasburg and lived with a nephew, who subsequently developed the disease. Turning to the evidence of history, there is the spread of leprosy throughout Europe, and, later, the rapid spread of the disease in the Sandwich Islands, where, though existing probably for many years, it increased from 1859, when it was hardly known, till in 1881 no less than 800 lepers were isolated, and it is said that no less than one-tenth of the population were affected. Another instance is the case of New Caledonia, in which the disease, though now common, is believed to have been introduced for the first time in 1860, and Pine Island, which is said to have been infected from New Caledonia; or Mauritius, which was infected by a single leper, and from which, later, the island of Rodriguez was infected, also by a single leper.

As to individual cases of infection by residence among lepers, the most noted is that of Father Damien de Venster, who went from Belgium as a missionary to the Molokai Leper Asylum of the Sandwich Islands in 1873, and who was first recognized to be suffering from the disease in 1882, from which he died in 1889.

Again, the prophylactic success of even partial isolation of lepers, as evinced in Europe in the thirteenth and fourteenth centuries, and to-day in Norway, Sweden, and Iceland, is in favour of the view that the disease passes from man to man. But it is not wise to hastily conclude that this transference is direct, for any of the above cases are easily explicable by the disease being conveyed by food or biting animals. The success of partial isolation might be simply to diminish the chance of infection by these means. Moreover, the fact that the attendants of the Hendela Leper Asylum of Ceylon have so far not been known to contract the disease is against the theory of direct contagion. Further, though there is evidence that married people may both suffer from the disease, there is no proof that sexual intercourse is a means of infection. Nor is there any evidence of heredity being a source of infection, for never has a child been born in a leprous condition.

If the germs are not carried from one person to another by contact, sexual or germinal transmission, they might still be conveyed by air, dust, water, or food, and, indeed, all these theories have their supporters.

It does not appear likely that it is conveyed by air, otherwise it would surely be spread more commonly from patients to attendants in leper asylums. With regard to dust, it is quite true that, though some persons report the presence of a very few bacilli in earth taken from places frequented by lepers, the majority have failed to find them; and, again, what has been remarked with regard to air also applies to dust. The germs have never been found in the water of the most highly infected places.

Many articles of food have been suspected, especially fish, and more particularly salted fish—a view which Sir Jonathan Hutchinson has strongly advocated; but even he admits that it will not explain all cases, particularly its presence in people who have no chance of eating even cured fish.

After excluding all these, there is still the possibility of the infection being carried by some blood-sucking insect. This subject has been most ably discussed by Nuttall, who points out that Linnæus and Rolander considered *Chlorops* (*Musca*) *lepræ* to be the active agent, while Corredor suspected flies in general, Sabrazés insects, Joly *Sarcoptes scabiei* and *Pediculi*, and Sommer mosquitoes. Nuttall himself says that the possibility of such transmission cannot be denied. Goodhue has demonstrated the bacilli in *Culex pungens* and in *Cimex lectularius;* and Marchoux and Bourret have suggested that some Simulidæ might be the carriers of the disease.

It might be thought that, direct inoculation having failed, the infection by means of insects would be unlikely. But that is not so, because it is well known that the passage of bacilli through another animal may markedly modify the virulence of the germ. On the other hand, a great many facts are in favour of the insect spread of the disease—*e.g.*, the infection in a family. The cases cited above as examples of contagion would be easily explicable by the action of an insect, as would the effect of isolation in preventing the disease. Moreover, the predisposing causes of dirt, poverty, etc., are also explicable on the same reasoning, especially the curious disappearance of the disease in the families of Norwegian peasants emigrating to America, where they became much cleaner in their habits. The difficulty of cultivating the germ on ordinary media is very suggestive of its being accustomed to live solely in animal tissues; while the abundance of the bacilli in the skin is also suggestive of that being the natural method of leaving the body. Everything in the history of the disease appears to favour its spread by animal agency.

Natives of Ceylon generally state that the disease begins after a bite by a rat.

Pathology.—According to different theories, the bacillus enters the body via the skin, the nasal or respiratory mucosæ, the alimentary canal, or the generative organs.

The list is so comprehensive that it will be obvious that the real method of entry is entirely unknown. On arrival inside the body, the bacillus is *supposed* to come to rest inside a lymph-space somewhere, and there to grow and form colonies, from whence it can be disseminated through the body, perhaps by the blood and the lymph streams. It must be remembered, however, that the nature of the initial lesions is quite unknown. So enormously do the bacilli multiply in the body that there are few diseases which show an equal infection.

The pathogenesis of the lesions is not very well known, and there are many points of dispute which so far have not been settled. The early stages have been most carefully studied by Unna in the neurolepride, in which there is at first a dilatation of the capillary vessels of the skin, on the walls of which the typical bacilli can be found. The organisms now pass into the wall of the vessel, and appear to irritate the connective-tissue cells of the vicinity, which, becoming plasma cells, surround the periphery of the vessel.

There is a dispute as to whether any diapedesis of the white cells takes place. Thus Thin and Neisser support the view of a diapedesis, to which however, Unna is opposed. According to the former observers, the cells of the leproma contain not merely plasma cells, but also leucocytes and lymphocytes, while according to the latter they are entirely plasma cells and their derivatives, for Unna holds the view that the bacillus has but little attraction for the white cell. The organisms pass from the vessel-wall into the lymph capillaries, in which they grow. These early stages have not been seen in the typical leproma, in which the bacilli from the first are met with in the lymphatics, in which they grow luxuriantly, causing the considerable dilatation which is a marked feature of the lesion.

Now occurs a phenomenon concerning which there is much difference of opinion, for either the plasma cells increase in size, and, becoming multinucleated, engulf the bacilli, forming in this way the typical 'lepra cells' of Virchow—a view supported also by Neisser and others—or the bacilli attack the plasma cells, destroy their cytoplasm, and so damage the nucleus that it becomes achromatic and breaks into several pieces, which remain surrounded by, or on side of a mass of bacilli embedded in mucus, thus giving rise to a false appearance of a giant cell or chorio-plaque enclosing bacilli, as asserted by Unna and others.*

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* Unna's staining method with Victoria blue and saffranin colours normal bacilli blue, and dead bacilli yellow.

The lesions show large cells—the 'lepra cells,' containing large masses of bacilli—but in addition to these cells there are also masses of bacilli embedded in mucus, and not enclosed in cells, which are the 'globi' of older writers, and which in fresh preparations appear as large, rounded, brownish masses. Sometimes typical giant cells, called 'Langhans' cells,' are seen, but these are really tubercular in origin. Marchoux and Bourret consider the so-called lepra cells to be undistinguishable from the large mononuclear leucocytes.

The bacilli do not invade the surface epithelium, nor a layer of the cutis directly below this ; nor do they affect the sweat glands, nor the hair sheaths superficial to the opening of the sebaceous glands.

The typical leproma, therefore, shows superficially epithelium, normal in every respect, except that there are no interpapillary processes. Below the epithelium there is a layer of connective tissue, free from bacilli, under which lies the typical lesion, composed of lepra cells, plasma cells, and connective-tissue cells, separated by a very slight amount of fibrillar connective tissue, and containing vessels, whose walls are thickened by an infiltration of the adventitia, media, and intima to such an extent that at times the lumen may be obliterated, while the lymphatic spaces are dilated and filled with bacilli surrounded by mucus, forming the 'globi.' Beneath the lesion the connective tissue may be more or less normal.

The attacks of fever and the erysipelatous eruptions, which will be described under the Symptomatology, are explicable by the dissemination of the bacilli throughout the body by the blood-stream, the bacilli being contained in the large mononuclear leucocytes, according to Marchoux and Bourret, and the embolism of the capillaries of the skin by bacilli and white cells, which, however, are soon recovered from.

Lesions may remain stationary for years, and retrogression may take place as the result of treatment, or spontaneously, in which case the dead bacilli are absorbed, and sac-like spaces left, which rarely become sclerosed by connective tissue. If on a surface, the leproma may soften, break down, and ulcerate, thus disseminating the bacilli in the discharge.

The bacilli may also enter into the nerves and cause a hyperplasia of the connective-tissue cells of the coats and the formation of typical leproma cells at first around the vasa nervorum, and later in the perineurium and endoneurium.

These cells press on the nerve fibres, causing a degeneration of the neurilemma, and later a disintegration of the arteries and a destruction of the nerve fibres, which finally results in the nerve being largely converted into connective tissue. In places where the nerve is apt to suffer from compression or other slight injuries, it becomes so thickened as to be easily palpable—a fact which Lie explains by saying that the bacilli which he found in the cutaneous nerves pass up the nerves and become located at spots liable to injury.

It is usually believedthat the nerves only are affected, and that the paralyses, etc., are the results of disease of the peripheral nerves, but recently it has been shown that the bacilli attack the anterior cornua of the spinal cord, and therefore this may play a part in the production of the symptoms.

The bacilli may be carried by the blood-stream all over the body, but show a selective affinity for certain organs, in which they develop the typical leprotic lesions. A certain number of leprotic subjects react to tuberculin injections, and give a positive Wasserman's reaction.

Morbid Anatomy.—The skin lesions which may be found are the tubercles, which may or may not be ulcerated, the pigmented and apigmented areas. On cutting into the leproma, it is seen to be situated usually in the cutis, and covered by the epidermis ; but it may lie in the subcutaneous tissue, in which case it does not form a tubercle. It is yellowish-white in colour, firm in consistency, and if squeezed, usually a little clear fluid can be obtained. It will be noted that the sweat and sebaceous glands and the hair-follicles are compressed and as a rule atrophied, while vesicles and pustules may occur on the surface, which may be ulcerated and covered with crusts. The macules consist of round-celled infiltration, with but few large cells, which are generally free from bacilli. In the spots which during life were anæsthetic, which are derived from the macules, the corium is largely converted into fibrous connective tissue, which has caused glands and hairs to atrophy and disappear.

The typical lepromatous infiltration may occur, not merely in the skin, but in the mucosæ of the tongue, pharynx, larynx, epiglottis, and in the submucosæ of the intestine.

The liver, which is usually enlarged, shows a leprous infiltration of the portal systems, while the spleen, which may also be enlarged, shows the same along the course of its vessels, particularly while they are in the septa, and a similar infiltration may be seen at times around the bronchi.

The ovaries and testes may show infiltrations and fibrosis of the interstitial tissue, which destroys the secretory elements, and causes the sterility which is usually so marked among lepers. The lymphatic glands are often enlarged, infiltrated, and full of bacilli, especially the femoral. Nephritis and leprous infiltration of the kidneys may be seen. The nerves most commonly affected are the palmar branch of the ulnar, the ulnar, the median, the peroneal, posterior tibial, and the great auricular. When exposed, the nerve is seen to show a fusiform, reddish-grey swelling, which, when examined, is found to consist of lepromatous tissue lying among the nerve fibres.

In the spinal cord there may be posterior sclerosis and meningitis, though it is doubtful whether these are really due to the disease or to some complication. The cells of the posterior cornu have been said to be atrophied, as well as those of the anterior cornu, in which Lie has found bacilli.

In the circulatory organs peri- and endarteritis, phlebitis, are met with, while osteomyelitis, necrosis, caries, and absorption of the bones may be seen, and will be mentioned again later. Trophic changes in the joints and perforating ulcers are met with in the nerve form of the disease.

Symptomatology.—The incubation period is entirely unknown, and must necessarily remain so until the method of infection and the date of the onset of the disease is discovered ; hence the statements made by the different observers that it may last for a few weeks or months up to many years. The method of invasion is also quite unknown. Sticker suggests that it begins with nasal symptoms—blocking of the nose, epistaxis, and frontal headache ; other observers with skin eruptions. The truth appears to be that so far the initial lesions and their symptoms, if any, have escaped notice.

Before the eruption appears there are, in many cases, attacks of fever of an intermittent or irregular character, with a marked feeling of general illness, associated with headache and pains in different parts of the body, peculiar sensations of cold, formication or numbness in various places, and, above all, of abnormal local or general perspirations. These attacks of leprotic fever, without any definite clinical signs of leprosy, may occur at intervals for years. This fever is probably due to the dissemination of the bacilli through the body, and may represent a septicæmic process due to the *Bacillus lepræ.*

After the general dissemination through the body, the bacilli appear to settle mainly in the skin or in the nerves, though, of course, there are many cases in which they settle in both. It is therefore convenient to distinguish the two varieties of the disease, first differentiated by Danielssen and Boeck—viz., 'lepra tuberculosa,' or 'nodular leprosy,' and 'lepra maculo-anæsthetica,' or 'smooth leprosy'—remembering that the division is artificial, and that numerous cases exist which show both forms.

TUBERCULAR LEPROSY.

After repeated attacks of fever the patient has a more severe one, during which an erythematous diffuse or macular eruption appears on the face and limbs. The fever subsides, and the maculæ may disappear or thicken and become tubercles, which are dermal lesions projecting from the skin or muscosæ, in addition to which there are subdermal infiltrations, which can be more easily felt than seen. If they disappear, it is only for the time, as new maculæ will appear with a new attack, and sooner or later the thickening will take place, and the nodules or tubercles, typical of the disease, will appear. Each outbreak of nodules is in some cases preceded by an attack of fever, with or without an erysipelatous-like eruption in the area to be affected, associated with the enlargement of the lymphatic glands. In our experience, however, the fever may be absent in many cases.

The nodules may form all over the skin, but are most common on the face and limbs. In the former situation they appear on the forehead, cheeks, alæ of the nose, lobules of the ears, lips, and chin, and as they increase in size, totally alter the appearance of the patient, defacing the natural facial lines, and forming new furrows between adjacent nodules; while at the same time, in many cases, the hair of the beard, moustache, and eyebrows drops out. These changes result in the countenance becoming like that of a satyr or, when the furrows are more marked, like that of a lion; hence the terms 'satyriasis' and 'leontiasis,' which the ancients applied to the disease.

Eye lesions are more commonly met with in this form of the disease, for Borthen, as the result of his investigations, concludes that only 8·08 per cent. of women and 1·67 per cent. of men suffering from tubercular leprosy escape without some form of disease of the eyes or their adnexa. Women are, however, less affected than men, but age shows no influence on the production of eye affections. In tubercular leprosy the eye is attacked by genuine leprotic lesions, and secondary infections are rare.

The supraciliary region, as has already been mentioned, is early attacked, and complete madarosis is not uncommon, and, later, paralysis of the frontalis muscle sets in. The eyelids are often attacked by diffuse or nodular lepromata, which may be merely extensions from the disease already attacking the supraciliary region, or may be quite distinct lesions. As a result of ulceration of these nodules, the eyelids may be destroyed.

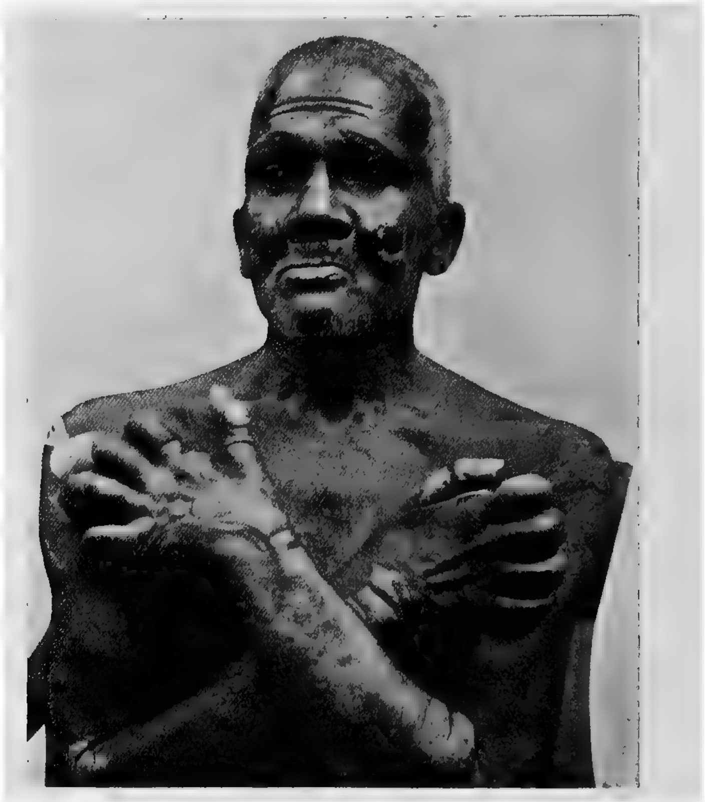

FIG. 313.—LEPROSY SHOWING THE ERYSIPELATOUS-LIKE ERUPTION ON THE ARMS AND FACE.

The conjunctiva may be infiltrated, leading to hyperæmia, or, more rarely, anæmia, and producing lagophthalmos, ectropion, and, if cicatrization takes place, xerophthalmia.

The episclera is apt to become infiltrated along the external aspect of the corneo-sclerotic junction, resulting in white, grey, or yellow flattish masses, which spread round the cornea dorsally and ventrally, and are prone to invade its tissue in the form of a diffuse infiltration, which spreads from the outer side towards the pupil.

More rarely small spots form on the cornea, giving rise to the 'keratitis punctata leprosa' of authors.

The disease may also spread to the uveal region, in the form of an infiltration, which causes an anterior or posterior iritis; or, more rarely, nodules may form in the ciliary body or near the canal of Fontana, giving rise to an irido-cyclitis or irido-choroiditis.

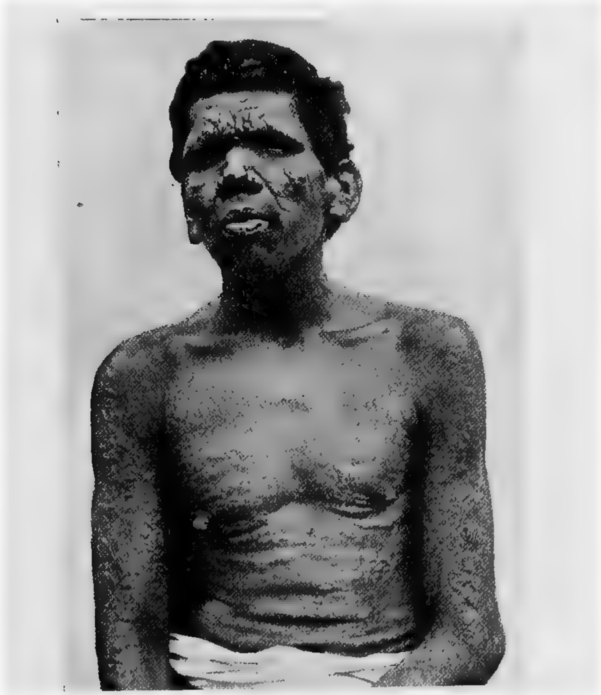

FIG. 314.—TYPICAL TUBERCULAR LEPROSY, SHOWING THE LEONINE EXPRESSION, THE THICKENED SUPERCILIARY RIDGES, AND THE MADAROSIS.

Lie has studied the pathology of these lesions, and has shown that it is rare for the optic nerve, the retina, the lens, and the vitreous humour to be affected.

The mucosæ of the nose may be attacked, with, first, blocking of the passage, and then, when the leproma extends down to the cartilage and ulcerates, falling-in or destruction of the nose, with much disfiguration of the countenance, resulting from the cicatrization which follows the ulceration. The tongue may also be affected, and show numerous tubercles, separated by furrows, or it may be simply infiltrated. The walls of the mouth and pharynx may become lepromatous, which causes mastication and deglutition to be rendered difficult, while the same condition in the larynx makes the voice raucous, and may impede respiration, especially if there is ulceration and cicatrization.

The skin of the hands, arms, and legs also shows numerous raised tubercles, which may ulcerate. The submaxillary, cervical, and femoral glands may be enlarged, and may suppurate. The testes often become fibrous, and menstruation becomes irregular and stops.

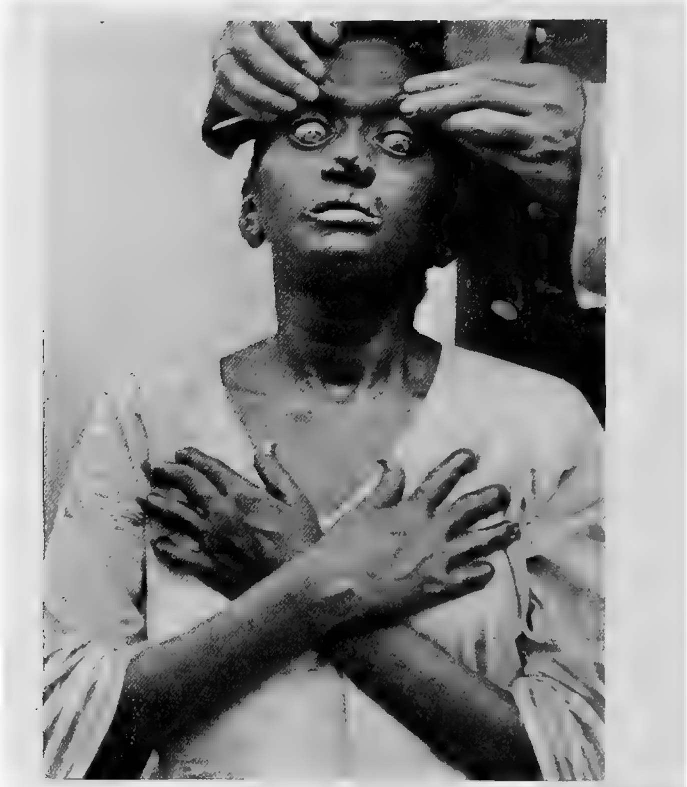

FIG. 315.—DIFFUSE INFILTRATION OF BOTH CORNEAS AND DEFORMITIES IN THE FINGERS OF THE RIGHT HAND.

In the early stages the blood shows no changes, but later it shows a diminution in the erythrocytes and a lowering in the colour-index. The red cells may show abnormalities in the form of poikilocytes, polychromatophilia, and basophilia. The number of leucocytes is generally normal, or, according to Bourret, diminished; while this observer records an eosinophilia in all stages of the disease, which he says may at times be quite considerable. Neutrophile myelocytes may also be observed. According to our researches the leucocytic formula is extremely variable, and is of no help in the diagnosis of the malady. Some authors state that they have found the specific bacillus in leucocytes, or, more rarely, free in the peripheral blood.

There are not many observations upon the urine. The most marked feature is a great increase in the ethereal sulphates. Brinton, of Rio de Janeiro, has isolated two ptomaines from the urine, one allied to choline and the other to muscarine.

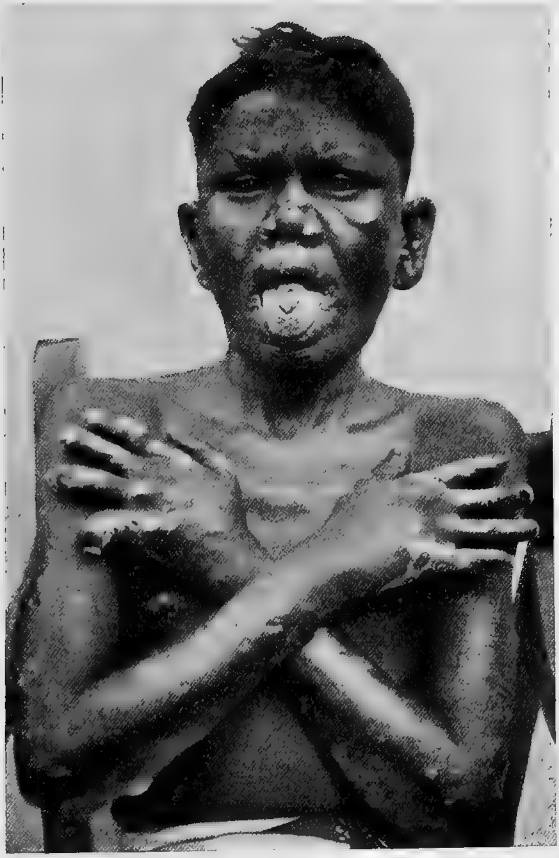

FIG. 316.—LEPROMA OF THE TONGUE.

The nerves may become attacked, and the signs and symptoms of nerve leprosy be added to those of the tubercular, forming a variety of mixed leprosy.

The ulcerations generally become marked towards the end of the disease. If treated, they cicatrize and produce deformities; if left to themselves, they suppurate and produce amyloidosis, or, becoming phagedænic, cause gangrene of the fingers or toes, and septic poisoning.

Complications, in the form of phthisis and amyloidosis, appear, causing fever, cough, and expectoration, diarrhœa, and enlargement of liver and spleen.

Unfortunately, in the midst of disease of almost every organ of the body, the mind is quite clear; but the patients are most irritable, and it is not surprising that, under these circumstances, the patients of a leper asylum require considerable tact in management, and are often peevish and discontented, and that small rebellions occur.

MACULO-ANÆSTHETIC LEPROSY.

In this form of leprosy the infiltration takes place principally into the nerves, with the result that first the fibres are irritated, and later they become destroyed. The first stage is therefore one of irritation of the nerves, with such symptoms as shooting-pains down certain nerves, especially the ulnar and the peroneal, accompanied with sensory disturbances, such as burning, numbness, formication, along with vasomotor disturbance—*e.g.*, flushings of the face, glossy skin—and motor disturbance, such as twitching of the muscles, particularly of the face.

Sooner or later a macular eruption appears, which is looked upon by some as due to a lepromatous infiltration of the skin, and by others as nervous in origin. This macular eruption may appear as flat red spots of various shapes and sizes, neither hyperæsthetic nor anæsthetic at first, which appear without fever or any general disturbance of the health. Other maculæ may appear which, instead of being red, are simply pigmented, while still others may be seen in which the pigmentation is less than usual. In any case, the spots grow larger, the centres becoming pale, while the peripheries, which are usually raised, and occasionally marked with papules or vesicles, or covered with dry whitish scales, may coalesce with other spots, forming large areas.

The skin in the affected area becomes anæsthetic; the hairs fall out, and wrinkles and scales appear. After a time the areas cease to spread, the raised margin disappears, and the disease becomes quiescent.

Meanwhile the infiltration into the nerve trunks has proceeded to such an extent that a swelling can be easily felt in certain regions—as, for example, in the ulnar behind the internal condyle, in the great auricular over the sterno-mastoid, in the peroneal just below the head of the fibula, and in other nerves in suitable places if affected. With the destruction of the nerve fibres, the hyperæsthetic stage ceases and the anæsthetic stage of the disease begins. This is to be noticed along the ulnar side of the hand, forearm, and arm, or on the inner side of the foot, first of all, and afterwards in other places. It may be segmental in arrangement, restricted to the distribution of a nerve, or in patches. At the same time the muscles begin to be paralyzed, notably the interossei of the hands, but also those of the foot, if carefully looked for. The lower efferent neurones being affected, the symptoms resemble those of muscular atrophy of the Aran-Duchenne type, with the production of the main-en-griffe and the extension of the paralysis to the muscles of the forearm, and even at times, according to Jeanselme, to the deltoid. As a result of the paralysis of the muscles of the forearm the occurrence of dropped wrist is not uncommon.

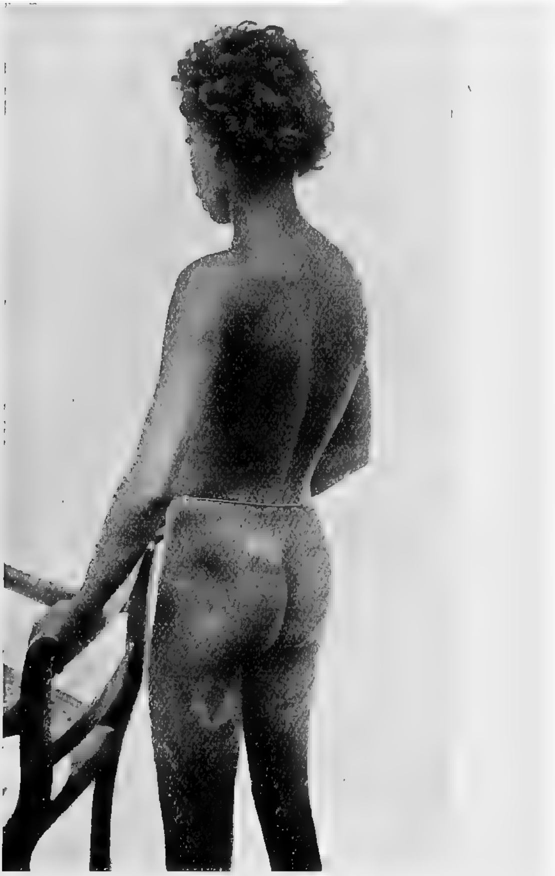

FIG. 317.—MACULO-ANÆSTHETIC LEPROSY.

In the lower limb the plantar muscles of the toes may be affected, while the spread of the paralysis to the peronei and extensors may result in a dropped foot with an internal twist. The reflexes are exaggerated at first, but when paralysis sets in they diminish, and when the muscles waste, the reaction of degeneration may be obtained electrically.

Trophic lesions may also appear in the form of whitlows in the fingers and necrosis of the phalanges, or, instead of this, a simple absorption of the bone of the phalanx or metacarpal, so that the nail may ultimately appear to spring from the metacarpal, the wrist, or even, it has been said, from the elbow. Similar trophic lesions may appear in the foot. Bullæ may appear on the hands or feet, and when broken may form ulcers. Injuries to anæsthetic areas may also result in ulcers, which may be of the perforating type. Fissures may form in the digits, hands, or feet, and, more rarely, dry gangrene may cause loss of the fingers or toes, or greater portions of the limbs, and, still more rarely, the bones of the fingers will soften and become osteomalacic. Trophic lesions of the elbow or knee, like Charcot's joints, have been recorded.

Jeanselme, Bourrett, and one of us have studied the cerebrospinal fluid, and have found in a few cases a lymphocytosis, but more usually no cells or bacilli.

The eye is far less commonly affected than in the tubercular variety, Borthen's figures showing that in anæsthetic leprosy no less than 36·83 per cent. of the female cases and 26·80 per cent. of the male cases escape without eye complications. True leprotic lesions are much rarer, the eye being damaged by secondary infections brought about by the absence of the lachrymal secretion and the lagophthalmos. The forehead and supraciliary regions are often reddened and œdematous, but complete madarosis is rare; while paralysis of the frontalis, corrugator supercilii, and orbicularis palpebrarum cause lagophthalmos and ectropion; and as there is a diminution in the secretion of tears, xerophthalmia with posterior or total symblepharon, while desiccation and destruction of the cornea may result.

Secondary infections may lead to keratitis, onyx, hypopyon, iritis, irido-cyclitis, and destruction of the eye.

Sterility is not so frequent in nerve as in the tubercular leprosy. The skin may become infected at an early or late stage of nerve leprosy, thus forming one of the types of mixed leprosy.

Mixed Leprosy.

This term has been used to comprise those cases of tubercular leprosy which develop nerve symptoms, and those of maculo-anæsthetic leprosy which develop nodules, as well as those general cases in which both nerve and skin lesions advance hand in hand.

Paraleprosis.—Zambaco, Von Duhring, and Glück have recently drawn attention to various phenomena indicating an attenuated infection in regions in which leprosy has long existed. These conditions are mostly nerve or trophic changes—*e.g.*, thickening of the ulnar nerve, the curving of the fingers, the loss of phalanges, the atrophy of the muscles of the hand or face, which are present in the children or grandchildren of lepers. Further, it is believed by some authors that syringomyelia and Morvan's disease may be modified forms of leprosy. Paraleprosis, however, requires further investigation.

Complications.—The important complications of leprosy are nephritis, phthisis, chronic enteritis, and dysentery. Amyloidosis occurs in the internal organs if there is much discharge from ulcerated surfaces.

Diagnosis.—The diagnosis of cases of the nodular type is generally easy, and may be readily confirmed bacteriologically by excision of a nodule and microscopical examination of a portion for Hansen's bacillus. The diagnosis of the maculo-anæsthetic cases presents greater difficulties, especially as in most cases the bacteriological examination of excised portions of the patches will give a negative result, though occasionally the examination of the blood taken from the patches or the surrounding zone may show a few mononuclear leucocytes containing bacilli. In these cases the diagnosis must be based on the presence of anæsthesia in the erythematous, non-pigmented or hyperpigmented patches. Another valuable sign will be, in many cases, the palpable enlargement of the ulnar, peroneal, and other nerves. The search for the lepra bacillus in the nasal mucus is sometimes useful to clear the diagnosis. It is to be noted, however, that this examination will give a positive result much more frequently in nodular cases than in the macular type of the disease. This method of diagnosis may be facilitated by administering a full dose (30 grains) of iodide of potash, which often produces nasal catarrh. Sometimes this drug produces a general reaction accompanied by fever, and the appearance of fresh nodules.

Some authors recommend the blistering of the skin, and examination of the liquid of the blebs for the presence of Hansen's bacillus. Thompson recommends for diagnostic purposes the injection of pilocarpine, with the view of discovering dry areas in the sweating skin.

Prognosis.—The prognosis is not good. The probability of a permanent cure is slight, but the disease may last a long time. Four to twelve years is laid down for the mixed or tubercular leprosy, and longer for the maculo-anæsthetic, and during that time a great deal can be done by appropriate treatment; and, indeed, the disease may be stopped for the time being, only, of course, to recur again. It has been shown recently by Lie that, even when all the skin eruptions have disappeared, and the patient is only troubled by anæsthesia and the atrophy of the muscles, and may be thought to be cured, still the bacilli are present in the nerves and spinal cord.

Treatment.—So far no specific treatment has been found, though Carrasquilla attempted to prepare a serum by the injection of the blood of lepers into equines, and Abrahams and Hermann by inoculating the juice from lepromata into an animal. These sera have been found useless. Rost prepared a substance, which he called 'leprolin,' on the lines of tuberculin, but, unfortunately, the bacillus he was using was not the leprosy organism. Tuberculin has been tried without success, and, in fact, very serious symptoms may follow its injection.

As regards symptomatic treatment, there is no doubt as to the great value of Chaulmoogra oil, which should be obtained by cold expression from the seeds of some species of *Gynocardia*, but may be adulterated with other oils, especially that of *Hydrocarpus wightiana*, or may be altered by being expressed when heated. It should be rubbed into the diseased patches, and also given internally in doses of 5 to 10 minims, working up gradually to 30 to 60 minims, in capsules, or in a pill with tragacanth and soap, or in an emulsion, or as engel-antileprol capsules. To remove the after-taste a lime can be sucked. This treatment must be persisted in for a very long time, and should be combined with hot baths, and, in nerve cases, with doses of strychnine— $\frac{1}{60}$ grain three times a day, which may gradually be increased. After a length of time it is as well to make a slight break in the treatment, to prevent toleration, and therefore Unna's ointment of ichthyol, 5 per cent.; salicylic acid, 2 per cent.; and pyrogallol, 5 per cent., or some other ointment, may be temporarily substituted. But the Chaulmoogra oil must not be long discontinued, and must be persisted in for two years or longer if any good is to be obtained.

Neumann has recently advised the combination of salve and theonin with Chaulmoogra, given either by the mouth or hypodermically, but the advantages are doubtful.

Other remedies are legion—*e.g.*, X rays have been well spoken of, but must be pushed to the extent of almost burning the patient. A 10-inch spark-coil with a bifocal tube, situate 7 to 10 inches from the lesion, has been used. Hypodermic injections of perchloride of mercury, as advocated by Crocker (0·01 gramme every other day), have been found satisfactory at times—a treatment which we recommend in cases at the very beginning of the disease.

Cashew nuts (Beauperthuy treatment) have been applied to the lepromata with the idea of local caustic action. Thyroid gland, salol, salicylates, arsenic, Gurjon oil, chlorate of potash, iodine, hypodermic injections of iodoform, have all been tried and found wanting.

Recently good results have been observed by using hypodermic injections of 'nastin,' which is a fatty principle extracted by Deycke from cultures of a streptothrix (*Streptothrix leproides*), which he found in the nodules of leprotic patients. The nastin is combined with benzoyl chloride, and made into ampoules with sterilized olive oil by Kolle and Company, of Biebrich, on the Rhine. Each ampoule contains from 0·0005 to 0·0002 gramme of nastin, which is to be injected once a week, and in the small doses produces no local reaction, but in the larger doses causes considerable local inflammation. Deycke's views as to the method of action are that the nastin attaches itself to the lepra bacillus, and then the benzoyl acts on the bacillus, damaging it by removal of its fat, when the normal fluids of the body complete its destruction.

Castellani and Woolley, and more recently Nicholls, have tried a vaccine prepared by triturating nodules rich in bacilli in salt solution or broth, then filtering through gauze, and finally heating to 60° C. for an hour.

Pasini has tried Finsen light and Beurmann radium with good results, and Duque, Moreno, and Padilla have obtained considerable improvement, and it is said cures, by treatment with decoctions of 20 to 60 grammes or 2 to 5 grammes of the powdered mangrove *Rhizophora mangle*, which, given in small doses at first, and gradually increased, are well stood, and produce a gradual improvement in the symptoms; and in the course of a year, it is said, cases may be cured.

Surgical treatment on the ordinary lines is required for ulcers, whitlows, etc. Eye lesions should be treated as though the disease was non-leprous, and should not be neglected. Grossmann thinks that leprous infiltration might be arrested by the production of cicatricial tissue, by a corneal or pericorneal incision.

With regard to other measures, lepers should be provided with plenty of fresh air and good food, and their quarters should be kept strictly clean. Care should also be taken that they are supplied with some form of light work and amusement.

Prophylaxis.—Beyond isolation and antiseptic precautions after handling leprous people, nothing more can be done, as so little is known about the causation of the disease. The financial burden of isolating large numbers of lepers is very heavy. Hence the difficulty of carrying out this very necessary method of protection completely and efficiently.

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CHAPTER XXXVII

FRAMBŒSIA TROPICA (YAWS)

Synonyms—Definition — History — Geographical distribution—Ætiology — Pathology — Symptomatology — Diagnosis — Prognosis — Treatment — Prophylaxis—References.

Synonyms.—In the British Colonies the disease is usually called 'yaws'; in the French colonies 'pian.' In Venezuela and other South American countries the name 'bubas' is much used. Other local names are 'gattoo' (West Coast of Africa), 'dubi' (Gold Coast), 'framosi' (Calabar), 'ab oukine' (Gaboon), 'tetia' (Congo Coast), 'momba' (Angola), 'parangi' (Ceylon), 'buena' (Burma), 'puru' (Borneo, Federated Malay States), 'patek' (Dutch Indies), 'tonga' (New Caledonia and Loyalty Islands), 'coco' (Fiji), 'tona' (Tonga Island), 'lupani tono' (Samoa), 'galis pateros' (some parts of the Philippine Islands). The term 'frambœsia' was first used by Sauvage in 1750 on account of the raspberry-like appearance of the eruptive elements. Charlouis in 1882 suggested the term 'Polypapilloma tropicum.'

Definition.—A tropical specific infectious disease caused by a *Treponema*, and characterized by a peculiar granulomatous eruption.

History.—It has been suggested by Hume, Adams, and others that frambœsia was the disease which afflicted the Israelites during their emigration from Egypt, and that therefore the term 'saraat' in the thirteenth chapter of Leviticus does not mean leprosy, as usually translated. Ali Abbas and Avicenna, who wrote at the end of the tenth century, mention a disease called 'safat,' or 'sahafati,' with symptoms not unlike those of frambœsia; but most authors are of the opinion that the disease referred to by the two Arabian physicians was syphilis. The study of the disease first began to engage the attention of European physicians after the discovery of America. Oviedo y Valdez (1478-1557) describes it in his work, 'Historia General e Natural de las Indias.' Piso (1648) refers to the malady in his work, 'De Medicina Brasiliensi.' Rochefort (1656), Raymond Breton (1665), and Labat (1694) report it from the West Indies, stating that it occurs frequently among the natives (Caribs), who called it 'pyans,' or 'yaya.' Bontius, in 1718, reported that frambœsia was endemic not only in the West Indies, but also in Java, Sumatra, and other Dutch colonies of the East, where it was known by the name of 'anboyna pox,' or 'pimple.' In the days of the slave-trade, outbreaks of frambœsia frequently occurred in the crowded ships carrying African slaves to America. Special hospitals for the isolation and treatment of slaves suffering from the disease were built on all the important estates in the West Indies. Occasionally in the countries in which it is endemic the disease may increase to such an extent as to cause veritable epidemics. An example of such an epidemic occurred in Dominica in 1871, when two special segregation hospitals had to be built for frambœsia patients.

In 1694 an outbreak of a peculiar disease occurred in Scotland. It was called 'sibbens,' or 'sivvens' (*sivvi*, Celtic for raspberry), and was apparently imported by Cromwell's soldiers. It was not improbably syphilis, but some authors suppose it to have been frambœsia.

The so-called 'button scurvy' of Ireland, endemic there in the eighteenth and the beginning of the nineteenth centuries; the 'radesyge,' which broke out in Sweden and Norway in 1710; and the 'mal de chicot' in Canada, have likewise been considered by some writers to be forms of frambœsia.

Several authors—Breda amongst the moderns—have endeavoured to distinguish between 'yaws,' 'pian,' 'boubas,' and 'parangi'; but those who have had the opportunity to study the disease in different countries have all come to the conclusion that 'yaws,' 'pian,' 'boubas,' and 'parangi' are simply different names for the same disease. The experimental researches of one of us in cases of frambœsia contracted in different parts of the world (tropical America, East and West Africa, etc.) show that 'yaws,' 'pian,' 'boubas,' and 'parangi' are merely synonyms.

Since the time of Labat several authors have upheld the syphilitic nature of frambœsia. This theory was supported till recently by Sir J. Hutchinson. In recent times the disease has been investigated, both clinically and experimentally, by a large number of observers.

In 1882 Charlouis proved by actual experiment that syphilis and frambœsia are two different diseases. The clinical investigation of the disease by Numa Rat was also of great value. His report, published in 1891, has become classical.

Among the recent observers who have investigated the disease in various parts of the tropics are Neisser, Daniels, Wellman, Jeanselme, Powell, Braush, Martin, Halberstadter, von Prowazek, Ashburn, J. Craig, and many others.

Geographical Distribution.—Frambœsia is essentially a tropical disease, as few, if any, genuine cases have been reported from places outside the Tropical Zone. At the present time a skin disease not unlike it has been reported from Greece by several writers.

Africa.—The disease is very rare in the northern regions of the continent. It is said to be occasionally met with in Algeria. It is apparently unknown in Egypt, though, according to some writers, it is observed in the Sudan. It is very common on the West Coast, especially on the Gaboon River, in the Congo Free State, and in Angola. It is also found in Mozambique, in Madagascar, and the Comoro Islands. In Uganda and the region of the Great Lakes it is occasionally met with. Griffith has observed it among the Kaffirs in South Africa near Kimberley.

Asia.—The disease is very common in the Malay Peninsula, Assam, Upper Burma, Siam, Java, Batavia, and is extremely frequent in Ceylon, where the number of cases treated in the Government Hospitals during the last eight years was as follows: 3,646 in 1900, 3,117 in 1901, 3,434 in 1902, 3,254 in 1903, 3,501 in 1904, 3,535 in 1905, 3,606 in 1906, 3,513 in 1907, and 3,246 in 1908. The patients treated in hospitals represent only a small portion of all the cases. In India it is very rare, though small outbreaks of the disease have been described by various observers. It occurs in certain parts of China, but is unknown in Japan and the central and western regions of the Asiatic continent. It is present in the Philippine Islands.

America.—It is very common in the West Indies, and occurs in British Guiana, Venezuela, Colombia, and Brazil. Cases have been reported from the southern United States, but never from the northern States nor from Canada.

Australasia.—The disease is absent from Australia, Tasmania, and New Zealand, but occurs frequently in many of the Pacific Ocean islands—Samoa, New Hebrides, New Caledonia, and Fiji.

Ætiology.—Different kinds of bacteria have been described as causative agents of frambœsia. Eijkman found some peculiar bacilli; Pariez observed numerous micrococci; Powell, in 1896, cultivated from two cases a yeast; Breda isolated from several cases a bacillus, which he named the 'frambœsia bacillus'; Nicholls and Watts, in 1899, isolated a coccus which, inoculated into animals, failed to reproduce the disease. In February, 1905, Castellani observed a *Treponema*, or spirillum, as he thought it at the time. This organism is now generally admitted to be the cause of the disease.

Treponema pertenue Castellani June 1905.—*Treponema pertenue* is an extremely delicate spiral-shaped organism, varying in length from a few microns to 18 and 20 μ and even more. It is extremely slender. Some individuals are, however, thicker than others. It does not stain easily, but good results may be obtained with Giemsa's method, and also with Leishman's stain, provided the alcoholic solution is allowed to act for five minutes, and the subsequent admixture with distilled water for from one half-hour to several hours. Using either of these methods, the Treponemata stain purplish. Occasionally a few more deeply stained granules may be seen in the body of the organism. The extremities of the parasite are often pointed, but forms may be met with presenting blunt extremities, or one extremity pointed and the other blunt. In some individuals one of the extremities may present a large pear-shaped expansion or a loop-like formation. The number of coils varies from six to twenty or more, but they are, as a rule, numerous, uniform, and of small dimensions. Occasionally a portion of the *Treponema* shows numerous close uniform coils, while the rest of its body shows no coils at all. Sometimes two Treponemata may be attached end to end, or apparently twisted together. Castellani has not been able to detect any undulating membrane, though its presence has been asserted by other observers (Blanchard). Occasionally, in preparations stained by Löffler's method of flagella staining, it has seemed to several observers that some of the organisms present an extremely delicate flagellum at one end. According to these observations, therefore, the organism is in all probability a *Treponema*, but further investigation is necessary to settle its true systematic position. From the above description it is evident that the frambœsia organism is morphologically very similar to that of syphilis. Blanchard, Martin, Prowazek, and others seem to have been able to make out some slight morphological differences between the two. Martin states that the frambœsia *Treponema* is even more slender and more difficult to stain than the *T. palladum* of Schaudinn. On the other hand, some authorities consider it to be thicker. Rivas states that it has closer coils. Prowazek, Levaditi, and J. Nattan-Larrier state that *T. pertenue* shows less regularly shaped coils, and one extremity terminates in a loop much more frequently than in *T. palladum*. We believe that the differentiation of the two organisms, and in general of spirochætes and Trypanosomata, is to be based more on the results of the biological tests than on slight morphological differences. The animal tests clearly show that *T. pertenue* and *T. pallidum* are two different species, inasmuch as monkeys immunized with *T. pertenue* do not become immune for *T. pallidum.*

Incidence of the T. pertenue in Frambœsia Lesions.—The presence of the *Treponema* is constant in the primary lesion and in the unbroken papules of the general eruption. It may be found in the spleen, lymphatic glands, and bone-marrow. In the blood it has not yet been demonstrated microscopically, though there is no doubt that the blood of the general circulation is infectious, inasmuch as monkeys inoculated with it develop typical yaws lesions in which the *Treponema* is abundantly present. The *Treponema* is absent in the cerebro-spinal fluid, and generally in the tertiary lesions.

Bacteriological Flora found in Open Sores of Frambœsia.—While *T. pertenue* is the only germ found in the non-ulcerated lesions, the ulcerated lesions of frambœsia are soon invaded by all kinds of germs. Apart from innumerable bacteria, various kinds of spirochætes are present. One form is rather thick, and takes up the stain easily. It is morphologically identical with the *Spirochæta refringens* of Schaudinn. Another form is thin, delicate, with coils varying in size and number, and with blunt extremities—*S. obtusa* Castellani. A third form is likewise thin and delicate, but tapers at both ends —*S. acuminata* Castellani; *T. pertenue* is also present in many cases.

Inoculation Experiments of Frambœsia in Man.—Paulet, in 1848, inoculated fourteen negroes with the secretion taken from frambœtic granulomata. All of them developed frambœsia, the inoculation period varying from twelve to twenty days, when at the seat of inoculation in ten cases the first nodule appeared, soon followed by a typical general eruption. In two cases apparently the eruption did not start from the seat of inoculation.

Charlouis, in 1881, inoculated thirty-two Chinese prisoners, who had never suffered from the disease, with crusts and scrapings from a case of yaws. The disease developed in twenty-eight of them, beginning invariably at the seat of inoculation. Moreover, he inoculated a native suffering from typical yaws with syphilis. The inoculation was quite successful, a primary syphilitic sore developing, followed by all the usual types of secondary eruption. That yaws patients are not immune against syphilis is proved also by Powell and Nicolas and others, who have described several cases of syphilis supervening on yaws. Syphilitic patients may contract frambœsia naturally and experimentally.

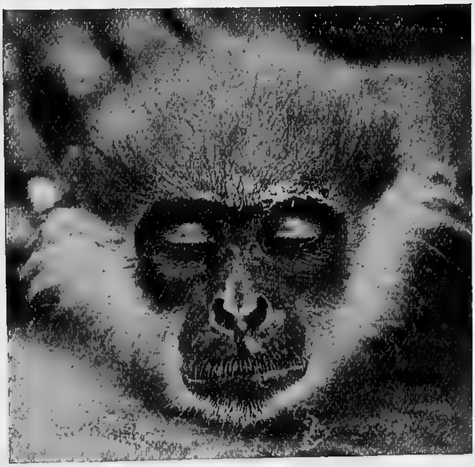


FIG. 318.—MONKEY INOCULATED WITH FRAMBŒSIA.

Inoculation Experiments in Monkeys.—Neisser, Prowazek, Halberstadter in Java, and shortly after Castellani in Ceylon, have shown that monkeys are susceptible to frambœsia. According to their experiments, the inoculation period varies from a minimum of sixteen days to a maximum of ninety-two. The appearance of the lesions developing at the seat of inoculation is practically the same in all cases—viz., an infiltrated spot slowly increasing in size, and soon becoming moist, the secretion drying into a thick crust. Removal of the crust exposes a raw, granulating, red surface.

In the monkeys of a low class (genus *Macacus*, genus *Semnopithecus*) the eruption is, as a rule, localized to the seat of inoculation. The infection, however, is general, as is proved by the presence of *T. pertenue* in the spleen and lymphatic glands besides the local lesions. Halberstadter has obtained a general eruption in ourang-outangs. According to Castellani's experiments, splenic blood, obtained by puncturing the spleen of a patient affected with frambœsia, can reproduce the disease in monkeys. The inoculation of the blood of the general circulation also may occasionally produce the disease. The inoculation of cerebro-spinal fluid into normal monkeys has always proved negative.

Neisser, Halberstadter, J. Prowazek in Java, and later Castellani in Ceylon, have proved that monkeys successfully inoculated with frambœsia do not thereby become immune to syphilis, and, *vice versâ*, monkeys successfully inoculated with syphilis do not thereby become immune to frambœsia. According to Levaditi, monkeys immunized for yaws do not acquire any immunity for syphilis, but monkeys immunized for syphilis may acquire a partial immunity for frambœsia. According to Ashburn and Craig, monkeys of the species *Cynomolgus philippinensis* are susceptible to frambœsia, but not to syphilis.

The following facts are in favour of the *T. pertenue* being the specific cause of frambœsia:

1. In the non-ulcerated papules, in the spleen, in the lymphatic glands of frambœsia patients, as well as in inoculated monkeys, the *T. pertenue* is the only organism present. No other germ can be demonstrated either microscopically or by cultural methods.

2. The extract of frambœsia material containing the *T. pertenue*, but, so far as our present methods of investigation permit us to say, no other germs, is effective when inoculated into monkeys.

3. The extract of frambœsia material from which the *T. pertenue* has been removed by filtration becomes inert, and monkeys inoculated with it do not contract the disease.

Predisposing Causes.—As is the case in other infectious diseases, dirt and other insanitary conditions favour to a certain extent the development and dissemination of the disease. The disease is rare among Europeans, and also among the better-class natives, who live amidst good sanitary surroundings, while it is very common among the villagers and low-cast natives, who live in uncleanly overcrowded huts. Sex does not exercise any influence, nor does age to any great extent, though the disease is more frequently met with in children and young people. The native practitioners of Ceylon are inclined to ascribe an important predisposing influence to certain foods. Some incriminate a kind of fish called 'balla mal,' others a cereal known as 'kurrakan' (nutcherr).

Pathology.—The histopathology of frambœsia has been investigated by Unna, Macleod, Jeanselme, Plehn, and more recently by Schüffner, Marshall, Shennan, Siebert, Ashburn, Craig, and Löhe. In the frambœtic papules the surface epithelium is greatly increased in thickness, and numerous elongated down-growths are seen. The epithelial layers show many patches, in which the epithelial cells are swollen, vacuolated, and degenerating. Small, sharply circumscribed areas are also seen containing polymorphonuclear leucocytes and detritus. The layers near the corium and its processes are, however, almost normal in appearance. The connective-tissue corium forms a thin layer, from which narrow, elongated, papillary processes pass into the epithelium, some of them nearly reaching the surface. The corium is the seat of marked œdema. There is a diffuse cellular infiltration made up of polymorphonuclear leucocytes, large and small mononuclear leucocytes, eosinophiles, plasma cells, mast cells, connective-tissue cells, and some extravasated erythrocytes. In the older nodules the plasma cells are present in such enormous numbers as to dominate all the others. Macleod has shown that there is no perivascular mononuclear infiltration so characteristic of syphilis, nor any endothelial proliferation in the vessel walls. The frambœtic lesion also differs from that of syphilis in affecting the epithelium rather than the cutis, in the more considerable œdema, and in the absence, as a rule, of the giant cells.

When the frambœtic granulomata have reached a certain stage, a very well-marked hyperkeratosis is noticeable. One of us has called attention to the appearance of the films taken in the usual way from the granulomata, and stained according to Leishman's method. In such films it is interesting to note the presence of a large number of polychromatic red blood cells of very different sizes, some much larger than the normal erythrocytes, some much smaller. They are stained deep or light blue instead of pink, and sometimes have a granular appearance. The leucocytes present in the films frequently contain in their protoplasm, and sometimes in their nuclei, roundish or oval, more or less deeply stained bodies, which are probably polychromatic micro-erythrocytes engulfed by phagocytes. In such films the Treponemata are almost constantly found. The Treponemata may be put in evidence also in sections by using the Volpino-Bertarelli or Levaditi's silver staining, as used by Spronk, Shennan, and Schüffner. The examination of sections so stained shows that the parasite is mostly found in the epithelial layers.

Symptomatology.— The course of frambœsia may be divided into three periods—a primary stage, comprising the development of the primary lesion; a secondary stage, during which the characteristic frambœtic granulomatous eruption appears; a tertiary stage, in which the late manifestations of the disease develop

—deep ulcerations and gummatous-like nodules. This division into three periods is somewhat arbitrary, as tertiary symptoms may appear during the secondary stage.

It has been stated again and again that the whole course of the disease lasts from three to six months in children, and six to twelve in adults, but according to our experience it has a much longer duration, and unless it becomes extinct after the secondary stage it may extend to many years. Indeed, we believe that in a certain number of cases, although there are periods during which the patient is apparently free from symptoms, the infection is merely latent, and sooner or later gives rise to renewed manifestations.

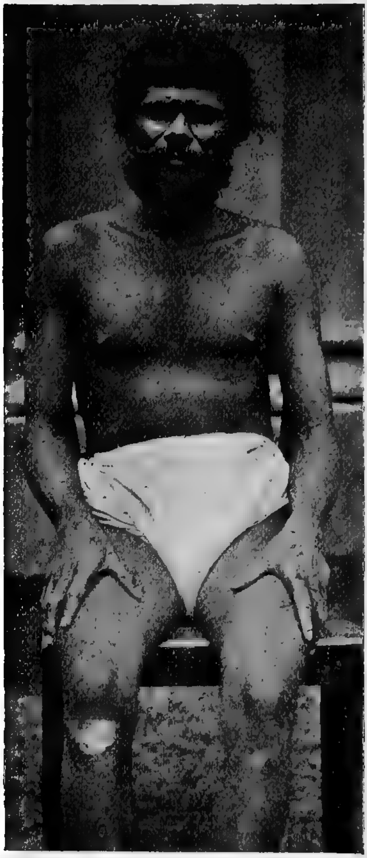


FIG. 319.—FRAMBŒSIA: PRIMARY STAGE, SHOWING THE PRIMARY SORE BELOW THE RIGHT KNEE.

(*a*) **The Primary Stage.**—After a period of incubation, varying in time between two to four weeks, characterized often by signs of malaise, rheumatoid pains, headache, irregular rise of temperature, the primary lesion appears at the seat of inoculation, which is generally extragenital. The primary sore is a papule, which after about a week becomes moist, developing a yellowish secretion, which dries into a crust. Often at the place of inoculation several papules appear, become moist, and coalesce into a single element, covered by a thick crust. If after some days the crust is removed, the primary sore will appear as an ulcer, not rarely of large dimensions, with clean-cut edges and a granulating fundus. This ulcer may heal, leaving a whitish scar, which may later become pigmented; or in other cases it may develop into a granulomatous mass, not dissimilar to the granulomata of the secondary eruption, which appear later on, but frequently much larger. This large single projecting nodule is called 'mother yaw,' or 'maman pian' in French patois. Occasionally round it, before the general eruption begins, several smaller granulomata develop like satellites. The primary sore never feels indurated, and is often painful during the first stage of development. Later it may be quite painless. Occasionally there may be pruritus. The proximal lymphatic glands may become hard and enlarged, but they do not suppurate.

The seat of the primary sore is usually extragenital. The lesion may develop on an old ulceration, an itch pustule, an insect bite, a wound, or a vaccination mark. The smallest abrasion is sufficient for the entrance of the virus. Most of our female patients presented the primary sore on one of the mammæ, developing on some crack or abrasion of the nipple and areola. In several other women the primary sore was found on the skin of the trunk, just above the hip, this being due to the custom of the Ceylon woman carrying her child astride of the hip. Any frambœtic element present on the scrotum or nates of the child, being continually rubbed against the skin of the mother, is likely to cause infection in the latter through any slight abrasion already present, or brought about by the friction. In men and children the primary lesion is frequently found on the hands, arms, and legs, but it may develop on any part of the body.

The primary sore may heal before the general eruption begins, but, as a rule, is still present when the secondary eruption appears. We observed a case in which the primary sore was still present six months after its first appearance, and when the secondary eruption had nearly undergone complete involution. The duration of the primary sore, therefore, may vary between a few weeks and several months. The primary sore leaves a whitish scar, which later on may become pigmented. In some cases the scar is small and smooth, in others it is large and very thick. It is to be noted, however, that in Ceylon the disfiguring scar so frequently seen is partly due to the custom the natives have of cauterizing the sore deeply by very primitive methods. In other cases the large disfiguring cicatrix is due to the primary sore having developed on an old ulcer, which on healing leaves a coarse scar.

(*b*) **The Secondary Stage.**—The general eruption usually begins between one and three months after the first appearance of the primary sore. It is preceded by malaise, headache, severe pains in the muscles, joints, and bones. In some cases there may be fever of an intermittent type. The patient, however, is ordinarily able to attend to his work. The general eruption develops as follows: Minute roundish papules, the size of pin-heads, appear on various parts of the body; some papules soon show a yellow point or minute yellow crust at their apex. Most of the papules remain of practically the same size for many weeks, and disappear, leaving occasionally some furfuraceous patches; others become larger, several often coalescing, and frequently acquiring a dark areola in natives, a reddish one in Europeans. Some of the larger papules increase in size, and develop into large granulomatous nodules covered with a crust, honey-yellow or brownish, formed of desiccated secretion. If the crust covering the granulomata be removed, there will be seen a raw surface throwing up red or yellowish fungoid granulations secreting a thin, slightly purulent secretion, which soon dries into a crust. These frambœtic granulomata are of various size, from a large pea to a nut, and may be found on practically any part of the body. They are extremely common on the upper and lower limbs, and on the face. On the scalp they are very rare. They may form rings round the mouth and anus, and may enclose sound skin. They may remain of the same size and appearance for months. Often, after a few weeks, the secretion diminishes, and a process of hyperkeratosis sets in. They then become of much harder consistency, and some of them, especially those on the dorsum of the feet and toes, may be covered with numerous small, hard, verrucose-like protuberances. In the majority of cases—within three to six months in children, and six to twelve months in adults—the granulomata dry up, shrink, and disappear, leaving dark hyperpigmented spots, or occasionally apigmented areas, on their site, which are most persistent. In some cases the granulomatous eruption may continue for several years, new crops of nodules appearing from time to time in succession. Each frambœtic granuloma generally undergoes involution within two to four months, leaving behind a dark area. Occa-

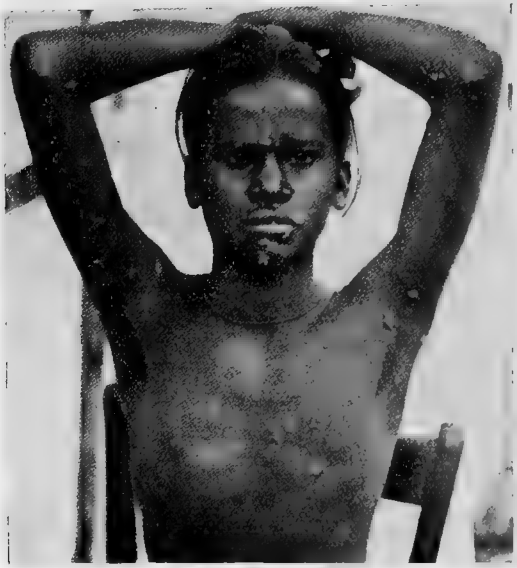
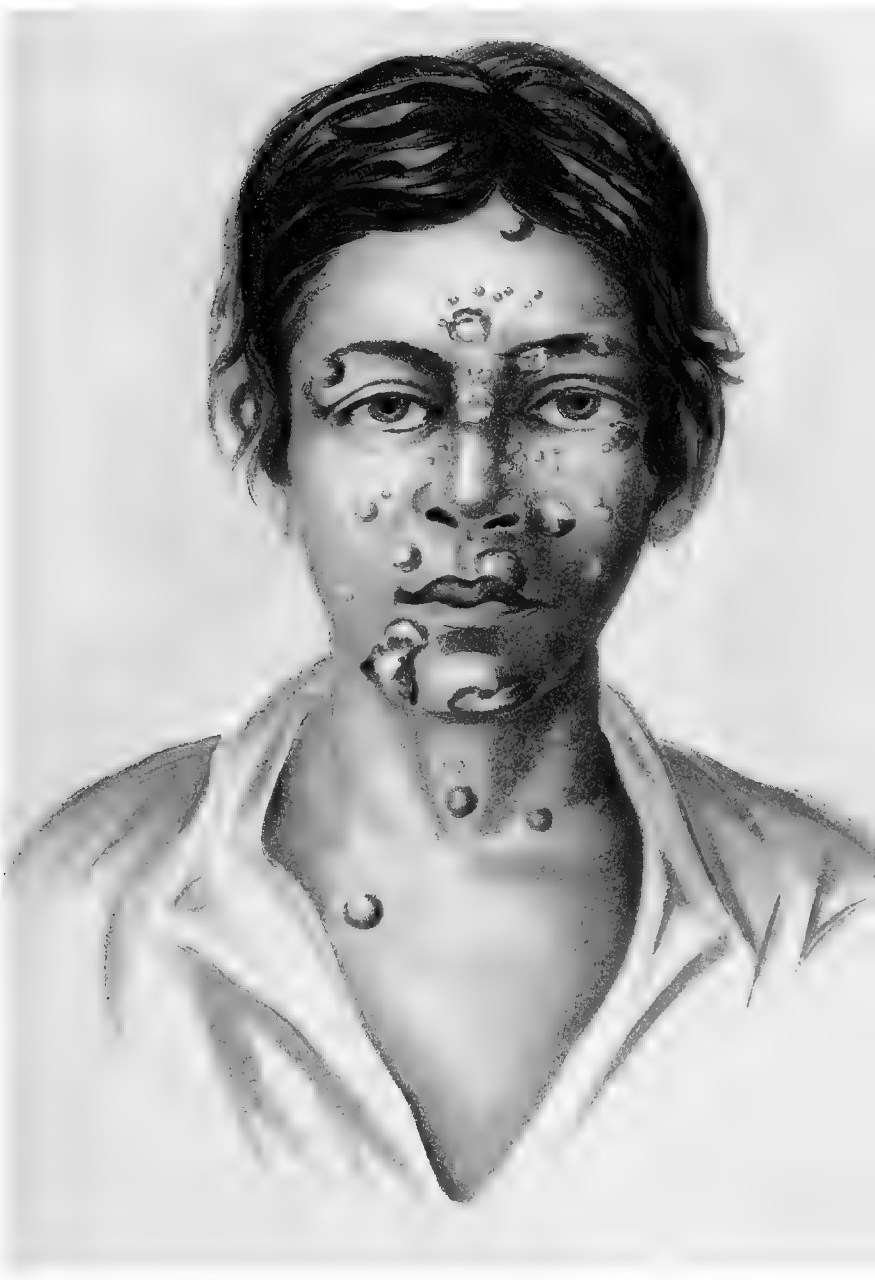


FIG. 320.—FRAMBŒSIA: GENERAL ERUPTION OF THE SECONDARY STAGE.

PLATE V.



FRAMBOESIA TROPICA.

GENERAL ERUPTION.

ston & Sons, Lith Edin.

To face

sionally, however, the granuloma does not regress so soon. In one of our patients a single granuloma persisted for two years after all the others had disappeared.

The granulomata are seldom painful, unless they develop between the toes, on the soles of the feet, or round the nails. They very often cause itching. The patient often exhales a peculiar offensive odour, which has been variously described as sour or musty. This is probably due to the growth of various bacteria, representing secondary infections beneath the crust of the granulomata. This offensive odour is especially noticeable when the secondary infection is due to bacilli of Vincent's fusiform type and coarse spirochætes. In such cases, if the sores are well washed with perchloride solution for two or three days, these organisms disappear, and the smell is no longer noticeable, though the granulomata do not undergo any change. Though the frambœtic granuloma is the characteristic eruption of the secondary stage, there are during this stage eruptions of different types—papular, scaly, and occasionally ulcerative. An average ordinary case will present at the same time several typical frambœsiform granulomata, numerous small

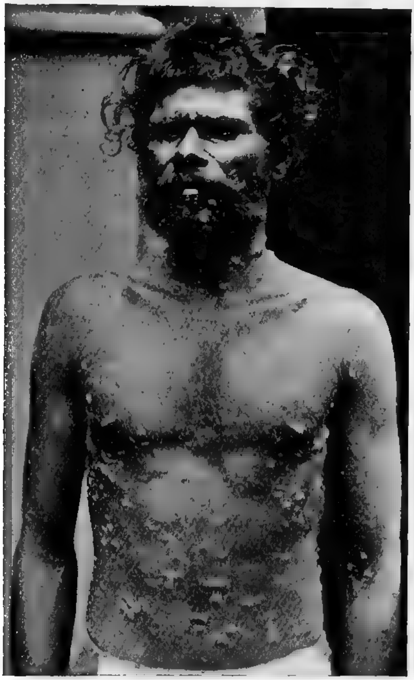


FIG. 321.—FRAMBŒSIA: SECONDARY STAGE, GENERAL ERUPTION.

reddish papules with the epidermis intact, other papules which have become moist and are covered by a tiny yellow crust, several furfuraceous patches here and there, and spots of increased pigmentation at the place of previous granulomata. Occasionally some granulomata break down, and large irregular ulcers form, presenting in their centre reddish papillomatous masses, which in our experience do not usually heal spontaneously. At times in the latter period of the secondary stage peculiar roundish or irregularly outlined whitish patches are present, especially on the back and arms, with a nutmeg-grater-like surface. On closer observation these patches are seen to consist of numerous hard, conical papules, containing in their centre an epidermic plug, which is easily removed, leaving a depression in the papules. Sometimes the plugs are spiny, and in this case the eruption closely resembles lichen spinulosus.

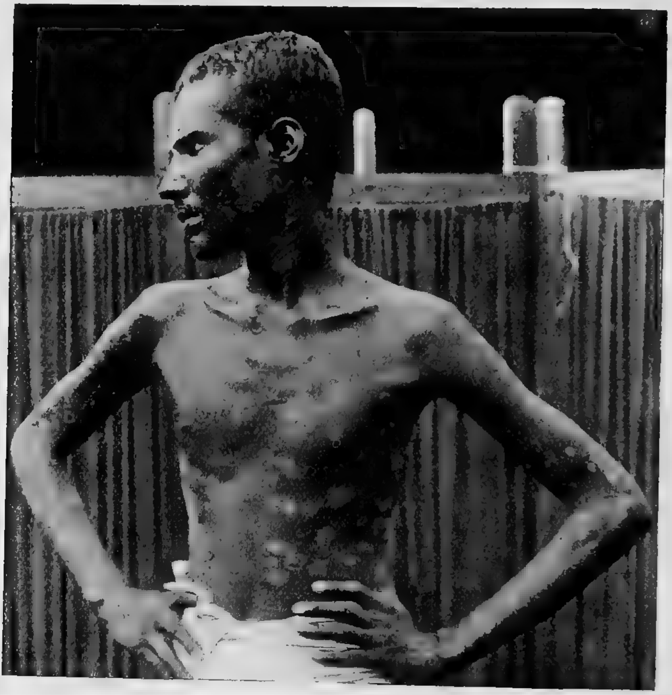


FIG. 322.—FRAMBŒSIA : SECONDARY STAGE, GENERAL ERUPTION.

ERUPTIONS ON THE PALMS AND SOLES.—The granulomatous eruption very frequently attacks the soles of the feet. At first dark-brownish or intensely livid spots appear ; the thick epidermis is gradually pierced by frambœsial nodules similar to those found in other regions of the body. This affection of the soles is very painful ; the natives of Ceylon call it ' dumas.' Similar lesions may occur on the hands. The granulomatous infiltration may attack the matrix and margins of the nails (frambœtic onychia and paronychia). The nails become thickened, dry, brittle, and may be cast off entirely, though later they grow again.

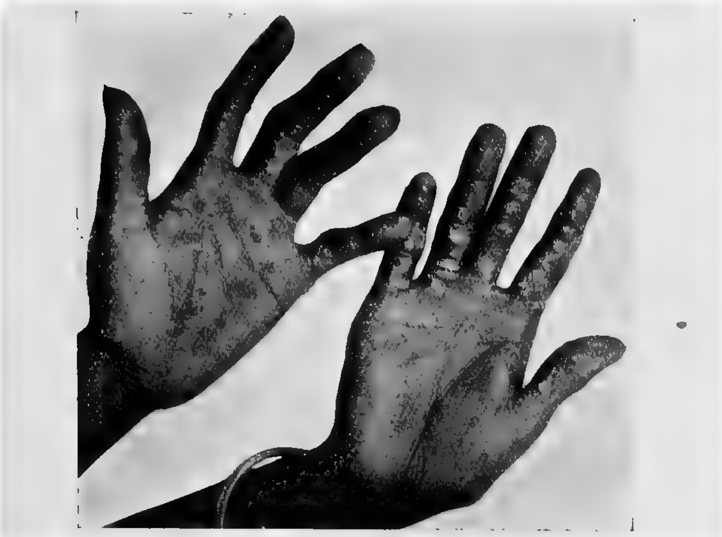


FIG. 323.—FRAMBŒSIA: ERUPTION ON THE HANDS.

After the granulomata have disappeared, occasionally at the same time, peeling whitish patches may be seen on the palms of the hands and soles of the feet closely resembling the syphilitic *psoriasis palmaris and plantaris.*

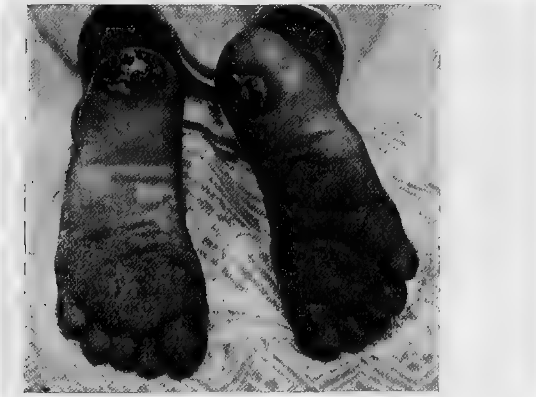


FIG. 324.—FRAMBŒSIA: GRANULOMATA ON THE SOLE OF THE FOOT.

PECULIAR PITTED APPEARANCE OF THE PALMS.—In several cases in the latter part of the secondary stage hard, round, flattened papules or small nodules, having a thick, hard, epidermic plug in their centre, may be observed on the palms and wrists. This plug falls off spontaneously or is easily pulled out, when a deep depression remains. The papules gradually disappear, but the depressions remain, and the palms acquire a peculiar pitted appearance. This condition of the palms may remain unchanged for several years after all symptoms of yaws have disappeared. A somewhat similar appearance of the soles of the feet is occasionally met with.

LESIONS OF THE HAIR AND NAILS.—We have never noticed any change in the appearance of the hair, or alopecia. A few hair-follicles may be destroyed when the granulomata develop on the scalp, which, however, seldom happens.

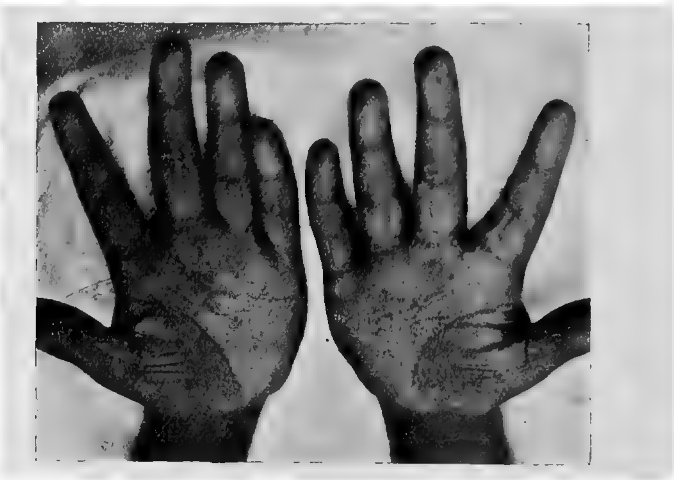


FIG. 325.—FRAMBŒSIA: PITTED APPEARANCE OF THE HANDS.

LESIONS OF MUCOSÆ.—These are not very common. During the secondary stage small granulomatous nodules may develop at the base of the tongue, also whitish patches closely resembling syphilitic leukoplakia. Small granulomata may develop on the nasal mucosa.

CONSTITUTIONAL SYMPTOMS—*Fever*.—As already stated, fever is frequently present, of intermittent or remittent type, before the general secondary eruption begins. During the secondary stage it is usually absent, unless complications supervene.

LYMPHATIC GLANDS.—In a number of cases in our experience various groups of lymphatic glands are found to be enlarged. The enlarged glands are roundish or spindle-shaped, hard, painless, and never come to suppuration, unless a secondary pyogenic infection is present. The cervical and inguinal glands are most frequently enlarged.

ALIMENTARY SYSTEM.—As a rule, the digestive functions are not disturbed. In children slight diarrhœa may be occasionally noticed preceding the general eruption. The spleen and liver are frequently found enlarged in children, but this is probably due to preceding or concomitant malaria infection. The microscopical examination of the fæces of frambœsia patients will frequently reveal ova of various worms—*Ascaris lumbricoides*, *Trichuris trichiura*, and occasionally *Agchylostoma duodenale*—but this is of frequent occurrence also in normal natives.

RESPIRATORY SYSTEM.—As a rule the respiratory, as well as the circulatory, system is not affected. Occasionally small granulomatous ulcers are to be found in the nasal mucosa, and more rarely in the larynx.

LOCOMOTORY SYSTEM—*Joints.*—In some patients several of the large articulations may become swollen and very painful. The condition is often of an acute character, and may be accompanied by fever, so that an attack of articular rheumatism complicating the frambœtic infection might be suspected. Sodium salicylate, however, is not beneficial, while the administration of large doses of potassium iodide speedily reduce the temperature to normal, and cause the swelling of the articulation to subside. At other times one articulation only is involved, and the symptoms may become so serious as to suggest purulent arthritis. In many cases the smaller articulations become involved. The symptoms in such cases are not acute, and there is usually no fever.

Bones.—Inflammation of the periosteum of various bones is of common occurrence. Very frequent is a form of multiple periostitis of the digital phalanges, the cause of the multiple dactylitis so often seen in frambœsia patients.

Muscles.—Contractures of various groups of muscles may be observed. Fairly common is a contracture of the flexor muscles of the forearms. This contracture is often permanent, and in our opinion is probably due to pathological alteration of the peripheral nerves, rather than being of direct muscular origin.

NERVOUS SYSTEM—*Neuritis.*—Neuralgic pains are often observed, but also a true form of neuritis must be admitted. We have seen in several cases clear symptoms of neuritis of the sciatic nerve, with severe pain along the course of the nerve, and signs of motor and trophic disturbances.

HYPERIDROSIS.—In several of our patients we have noticed hyperidrosis. The phenomenon was limited to the face in some cases, to the hands and soles of the feet in others. It never extended to the whole body, and always affected symmetrical regions. Hyperidrosis is more frequently observed in children than in adults. In a case at the Colombo Clinic a boy of fourteen, presenting a general eruption of frambœsia, the hyperidrosis of the face was so marked that large drops of perspiration were continually dropping down. He was treated with potassium iodide. After a month the granulomata had disappeared, and the hyperidrosis was no longer noticeable. In some cases the hyperidrosis ceases suddenly without treatment. The condition, however, may last for some weeks or months.

THE EYES.—Granulomatous and papular eruptions may develop on the eyelids. A slight periostitis of the orbital margin is not rare, the margin becoming thickened and very painful on pressure. The occurrence of iritis is denied by most authors. In the Colombo Clinic two typical cases were observed during the general granulomatous eruption. In both cases the affection was of moderate severity. There was photophobia, ciliary congestion, discoloration of the iris. Pupillary reaction was almost absent. Both cases recovered on large doses of potassium iodide without any local treatment.

THE GENITO-URINARY SYSTEM.—The primary lesion is rarely found on the genital organs. In fact, in all the cases we have seen the primary lesion was always extragenital. Eruptions of the secondary stage, papular and granulomatous, frequently involve the skin of the penis and of the labia. Granulomatous ulceration may be found on the vaginal mucosa. The urine, as a rule, does not contain anything abnormal; only when there is fever—as, for instance, when the articulations are acutely involved—then a slight amount of albumin may be present.

THE BLOOD.—There is often a certain degree of anæmia, never very severe. The number of red blood-corpuscles varied in our cases from 3,000,000 to 4,000,000, the hæmoglobin index (Fleischl) from 50 to 75. The red blood-corpuscles did not show anything abnormal in their shape. On several occasions a comparatively large number of polychromatic erythrocytes were noticed, staining blue instead of pink with Leishman's method. Many of these basophile red cells are micro-erythrocytes. The leucocytes varied from 7,000 to 11,000 per cubic millimetre. In the majority of cases an increase was noticeable in the number of the large mononuclears, even when there was no sign and no history of malaria. In almost all the cases the eosinophiles were increased, this being probably due—in part, at least—to the presence of intestinal worms, as revealed by the microscopic examination of the stools, which showed frequently ova of *Ascaris lumbricoides*, *Trichuris trichiura*, and in a few instances of *Agchylostoma duodenale*.

CEREBRO-SPINAL FLUID.—The liquid is in all cases perfectly clear, like distilled water. No cellular sediment on centrifugalization is found in most cases. In a few some rare mononuclear cells are found. The pressure is not increased. The physical and chemical characters do not show much variation from what is found in normal conditions. The density varied in our cases between 1003 to 1005. A certain amount of globulin was present, and a substance (dextrose ?) reducing Fehling's solution. This reducing substance was in several cases distinctly in excess of what is observed in the normal fluid. No cholin is found. The reaction of the fluid is alkaline. The liquid is sterile; no treponemata can be detected.

Tertiary Stage.—The disease often terminates with the secondary stage. In some cases, however, the infection does not become extinct, and tertiary lesions appear. These have been denied by many observers, but having been able to watch cases for several years through the whole course of the disease, we have no doubt as to their existence. Sometimes the secondary and tertiary stages merge into each other, but frequently the tertiary symptoms appear after the lesions of the secondary stage have undergone complete involution. The interval of time varies considerably in length, and may extend to many years. The characteristic lesions of the tertiary period are gummatous-like nodules and deep ulcerative processes. These gummatous nodules may develop in any tissues. When developed in the skin and subcutaneous tissues, they are indolent, and by their softening and breaking down ulcers are produced which may present clear-cut margins and a granulating fundus. When several contiguous nodules break down serpiginous ulcers are left. In other cases deep, irregularly shaped ulcerations with very thick and undermined edges are seen; in others, large fungating ulcers are present. On healing, these various ulcers leave whitish scars, which are often thick and disfiguring. Frequently the scar-tissue undergoes retraction, and causes thereby permanent contractures and disfigurement. Lesions of the osseous type are very frequent, painful nodes developing under the periosteum of several bones, ribs, sternum, etc. In other cases a diffuse chronic periostitis is present, altering the normal shape of the bones. Contractures of various groups of muscles are frequently seen. Tertiary affections of the internal organs and of the central nervous system have not yet been described. The malady does not appear to be hereditary; in fact, it is worth noting that, in contrast to syphilis, parents generally contract the malady from their children.

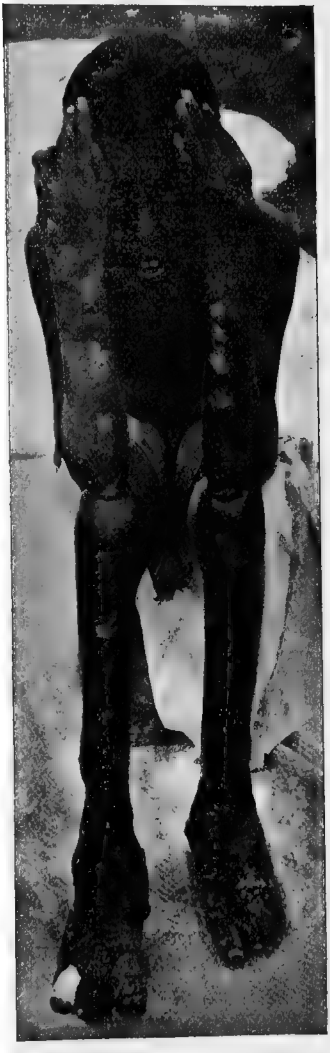


FIG. 326.—FRAMBŒSIA: TERTIARY STAGE.

Communicability.—Frambœsia is usually conveyed by direct contact from person to person. It appears, however, that the germ is unable to enter through the normal skin, and that there must be some pre-existing abraded surface, small wound, or ulceration. Women are frequently infected by their children, the primary lesion appearing often on the mammæ. In the native women of Ceylon the primary lesion frequently develops on the skin of the trunk just above the hip, slight abrasions caused by friction being usually present on this part, owing to the habit they have of carrying their children astride of the hip. In our opinion, however, there can be little doubt that in certain cases insects may carry the disease. It is very noticeable that flies eagerly crowd on the open sores of frambœsia patients. In the hospitals, as soon as the dressings are removed, the frambœtic ulcerations become covered with flies, sucking with avidity the secretion, which they may afterwards deposit in the same way on ordinary ulcers of other patients. Ants also are occasionally seen to go on to the frambœtic ulcerations, as well as on to ordinary ulcers. In Nuttall's classical work on the rôle of insects as carriers of parasitic diseases several authors are quoted (Alibert, Hoish, Cadet, Wilson) who believe that the infection may be conveyed from one individual to another by flies. Wilson states that this belief prevails among the natives of the West Indies.

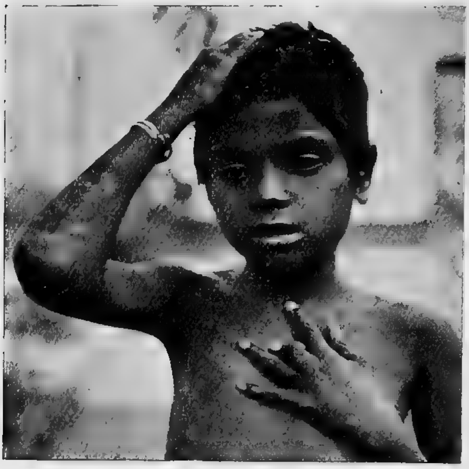


FIG. 327.—FRAMBŒSIA : TERTIARY STAGE.

One of us made some experiments to prove that flies are instrumental in the dissemination of the disease. A number of flies were fed on scrapings from slightly ulcerated frambœtic papules. The flies (*Musca domestica* and allied species), before feeding on the frambœtic material, were examined. The examination showed that they did not harbour any Treponemata, either on their mouth organs or on their legs. On examination after feeding, the majority presented coarse spirochætes, and a few of them also *T. pertenue.* In another experiment flies fed on yaws material were placed on scarified spots over the eyebrows of several monkeys, and kept there for two hours by means of strips of gauze smeared with collodion at their margins. One of the monkeys became infected.

Modder suggests that *Ixodes bovis—i.e., Margaropus annulatus* var. *australis*—or some of the argasidæ may be the transmitting agent.

Diagnosis.—In countries where the disease is endemic the diagnosis is generally easy, the frambœsiform nodules, capped with thick yellow crusts, being typical. By some observers the disease has been confused with *verruga peruviana* and with *syphilis.*

Verruga Peruviana.—This disease is strictly limited to certain valleys of the Andes at an elevation of from 3,000 to 10,000 feet. It is far more deadly than frambœsia, the mortality rising to 30 and 40 per cent. It is usually accompanied by severe fever of long duration, and its eruptive elements, unlike those of frambœsia, frequently attack the various mucosæ, and bleed with great facility.

Syphilis.—By some authors frambœsia has been looked upon as a form of syphilis. The results of experimental investigations on yaws and syphilis prove conclusively that the two diseases are distinct, inasmuch as (1) patients suffering from syphilis may contract yaws, and patients suffering from yaws may contract syphilis ; (2) monkeys successfully inoculated with yaws do not acquire any immunity against syphilis, and *vice versa.*

Syphilis has a world-wide distribution ; frambœsia, on the other hand, is restricted to certain parts of the tropics. Frambœsia is extremely common in Ceylon, extremely rare in India. Syphilis is common to both countries. In Samoa, according to Turner, syphilis was unknown up to at least 1880, while frambœsia has been endemic there ever since the group was discovered. In Fiji, too, up to a few years ago syphilis was not present, while frambœsia was almost universal. Daniels has made the interesting observation that in British Guiana frambœsia of late has disappeared, while syphilis is still rampant. As regards clinical features, frambœsia differs from syphilis by the following characters : The primary lesion is, as a rule, extragenital ; the principal type of eruption is a papule, which proliferates into a frambœsiform granulomatous growth ; there is an extremely well-marked pruritus. The histopathology differs also in the two diseases. In frambœsia the proliferative changes of the epidermis are much more marked, the granulomata present a more diffuse plasma cell infiltration, and their blood-vessels have no tendency to the thickening of their walls, which is so characteristic of syphilis. Giant cells are generally absent. Naturally these differential histological details must be considered collectively, as there is no individual histological character which exceptionally might not be present in both syphilis and frambœsia.

Boubas and Pian.—Some of the older authors believed that under the names of yaws, boubas, and pian three different diseases were indicated. Among modern observers, Breda has held the same opinion. All those, however, who have had opportunity to investigate frambœsia in different parts of the tropics have come to the conclusion that these various denominations are simply local synonyms indicating the same pathological entity. Castellani's comparative experimental investigations have led to the same result, inasmuch as he has been able to demonstrate that monkeys successfully inoculated with Ceylon frambœsia become immune to boubas and pian, and *vice versa.**

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* Rivas, Linderman, and Robledo have found the *T. pertenue* in their cases of boubas in Venezuela, Brazil, and Colombia. Breda and de Amicis, in Italy, have not found it in Italian emigrants returning from Brazil, and suffering from what they considered to be boubas. This term may therefore cover more than one disease.

Prognosis.—The prognosis is not serious so far as life is concerned. In 1908, in the Ceylon hospitals 3,246 cases were treated, with twenty-three deaths; in 1904, out of 3,591 cases, sixteen died; in 1903, out of 3,254 cases, ten only died. The prognosis is far more serious in children than in adults. When the disease ends fatally the termination is generally due to secondary infection, the frambœtic ulcerated lesions becoming phagedenic, and giving opportunity to septicæmia and pyogenic processes to develop. Though frambœsia rarely terminates in death, its long duration and great contagiousness render it a serious malady. The patients suffering from it are unable to attend to their work. Epidemics of frambœsia, therefore, are of the greatest consequence on tea, sugar, and other plantations, as they reduce the supply of labour.

Treatment.—The natives treat the disease in various ways. In Samoa the patient is rubbed down with sand and washed in the sea, after which the yaws are scraped with a shell. In the West Indies boiled and beaten-up leaves of the 'physic-nut' are applied, or powdered alum and sulphur used. In Ceylon the *vedaralas* (native doctors) apply concoctions of various herbs, and give decoctions of sarsaparilla and other roots. They also use mercury disguised in various ways. The majority of European practitioners use mercury and potassium iodide. Others affirm these drugs to be quite useless, and believe that cleanliness and good and abundant food are quite sufficient to bring about a cure.

In the Colombo Clinic for Tropical Diseases some experiments were made on the various treatments, and the conclusion arrived at was that the potassium iodide treatment is the most effective of all. Some cases may recover spontaneously, but this is certainly the exception, not the rule. The potassium iodide should be given in large doses (in adults 15 grains and in children 5 grains three times daily). Occasionally cases are met with refractory to treatment, and tertiary lesions are often intractable. The yaws patients usually bear large doses well. When severe symptoms of iodism set in, the doses should be temporarily decreased, or the treatment may be stopped altogether for a few days. Mercury is of very little use, as a rule. Atoxyl has been tried by Neisser in monkeys experimentally inoculated with the disease, and by one of us in human patients. The results are fairly good. In some very stubborn cases a course of potassium iodide, followed by a course of atoxyl injections (grains iij. every other day), can be recommended. An important point often overlooked by the practitioner is that the treatment should be prolonged for a considerable time after the complete disappearance of the eruption, inasmuch as clinical experience, as well as experiments on inoculated monkeys, prove that the specific treponemata may, and do, persist in the lymphatic glands and internal organs long after the cutaneous manifestations have disappeared.

Broden has tried antimonial preparations with good results.

Local treatment consists chiefly in keeping the skin scrupulously clean, washing the eruption twice daily with a perchloride of mercury solution (1 to 1,000), which greatly allays the itching. The ulcerated lesions may be dusted with iodoform, europhen, or boracic acid. Mercury ointments may be beneficial, but in our experience are not sufficient to hinder secondary pyogenic infections. Caustics are not called for unless the ulcers become phagedenic. In such cases pure carbolic acid is best. Though the external treatment may be useful, one must bear in mind that it is not, as a rule, sufficient alone to cure the disease.

Prophylaxis.—In countries where frambœsia is endemic the slightest abrasions of the skin should be taken care of and properly treated with antiseptics. Frambœsia patients should be prevented from mixing with the rest of the population, and should be isolated in special hospitals till the disease is cured. Their skin lesions should be properly dressed, and thus prevented from becoming a source of infection through the agency of flies and other insects. Their huts and belongings should be thoroughly disinfected.

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CHAPTER XXXVIII

VERRUGA PERUVIANA

Synonyms — Definition — History — Climatology — Ætiology — Pathology — Symptomatology — Diagnosis — Prognosis — Treatment — Prophylaxis — References.

Synonyms.—Peruvian Wart, Verruga Blanda, Carrion's Fever, Verruga de Castilla, Verruga of the Andes, Verruga de Zapo ó de Quinua, Verruga Andicola, Verruga Mular, Verruga de Sangre, Fièbre de la Oroya, Verruga de Crapaud, Bouton des Andes. The word ' verruga ' signifies in Spanish a wart.

Definition.—Verruga peruviana is a chronic endemic specific general disorder of unknown origin, not contagious, but apparently inoculable, and characterized by an irregular fever associated with rheumatoid pains, anæmia, followed by granulomatous swellings in the skin, mucous membranes, and organs of the body.

History.—It is probable that the disease existed in South America before the advent of the Spaniards, for the earliest references to it are found in Spanish works on Peru in the sixteenth century. The first record is by Agustiñ de Zarate, Treasurer of Lima, in his ' History of the Conquest of Peru,' written in 1543, in which he relates that warts or small tumours appeared on the face and other parts of the body, which were more deadly than small-pox, and almost as fatal as plague.

Garcilas de la Vega records that a quarter of the small army of François Pizarre perished from this cause, while Gomara, Garcilazo (1617), and other early writers also draw attention to the disease. After this period writers on Peru either fail to mention the disease at all, or only write short paragraphs such as that in Cosme Bueno's geographical description of the province of Canta, published in 1764, in which it is mentioned under its ancient name of ' berrugas.'

The modern descriptions of the disease begin with the works of Tschudi in 1843, Malo in 1852, Smith in 1858, Salazar and Manuel Odriozola in 1858, Velez in 1861, and Dounon in 1871, the last named giving a very clear account of the complaint.

But little interest was, however, taken in it until 1870, when a severe outbreak of fever took place among the work-people laying the railway-line between Lima and Oroya. This complaint for some reason was called 'Oroya fever,' although it did not affect Oroya. About the same time Dounon's excellent paper appears to have interested French naval surgeons, so that numerous investigations as to verruga and Oroya fever were made both by Peruvian doctors, such as Pancorvo and others in 1875, and French surgeons, such as Fournier in 1874, Bourse in 1876, and Tupper in 1877. During this period there was much disputation as to whether Oroya fever was related to verruga, or was a distinct clinical entity. In 1885 Daniel A. Carrion, a student of the Faculty of Medicine of Lima, who had for some time been studying the disease, attempted to settle this question by vaccinating both his arms with the blood from a verruga tumour on August 27, 1885, and on September 17 he began to suffer from the symptoms of Oroya fever, from which he died on October 5. In honour of this noble attempt to elucidate the ætiology of the fever, his compatriots have since referred to Oroya fever as Carrion's disease.

The unfortunate death of this brave young man stimulated inquiry, and a very large number of investigations were published, of which it is only possible to mention a few.

In 1885 Izquierdo announced the discovery of a bacillus in some specimens sent to him in spirit, which, of course, prevented anything of the nature of a thorough bacteriological investigation.

In 1887 Florez grew a coccus on agar-agar inoculated with the blood from persons suffering from verruga. In 1898 a most elaborate monograph by E. Odriozola appeared, which the reader interested in the subject is strongly advised to peruse.

In the same year Nicolle and Letulle independently described bacilli resembling those of tuberculosis in the skin lesions. Barton, in 1902, published the first careful bacteriological examinations of Carrion's fever, and from 1903 to the present time Biffi has written a series of able papers on the disease.

We are therefore confronted with two conditions described by authors—viz., a disease which may or may not begin with fever, and which ultimately ends with a most peculiar and typical eruption, verruga peruviana, and another disease characterized by an incubation period of twenty-one days, as proved by Carrion's inoculation, and of a severe type often ending in death, without the appearance of any eruption. Are these two conditions one and the same disease—that is to say, is Carrion's fever Peruvian wart without an eruption, or are the two separate pathological entities? Tasset, in 1872, held that they were separate entities, and that Carrion's fever was a typho-malarial fever, but since the inoculation of Carrion most authors have considered the two diseases to be one and the same, though every now and again some author has objected, and has held that Carrion's fever was typhoid. In 1901-02 Barton, as the result of careful bacteriological researches, concluded that in the blood and organs of persons dying from Carrion's fever a micro-organism could be found which, though similar to *Bacillus coli communis* in many respects, was easily separable therefrom. This organism was fatal to inoculated animals, causing a septicæmia and, it is said, a verruga-like eruption in the skin. Biffi has carefully investigated this bacillus, and finds that it is present constantly and in abundance in persons suffering from Carrion's fever, but is absent in patients suffering from verruga peruviana without fever. It is agglutinated by the serum of persons suffering from Carrion's fever, but not by that of patients suffering from verruga who have not had fever. The micro-organisms are, however, not always of the same strain. Thus, Biffi has separated two different strains, one of which resembles Schottmüller's *B. paratyphosus β.*, and the other Gärtner's bacillus. Biffi and Carbajal were unable to confirm Barton's results as to the presence of a skin eruption in animals inoculated by these strains. They therefore conclude that Carrion's fever is a separate pathological entity distinct from verruga, and that it is a fever belonging to the paratyphoid group, but differs from the usual types by being due to a different organism, and by occurring in patients suffering from verruga. In this finding they are supported by the clinical observations of several observers, among whom may be mentioned Eder.

The next question which must be considered is the nature of verruga peruviana, for recently it has been suggested that it is frambœsia, and this has been specially emphasized, since it has been realized that it may run its course without any fever. Biffi, however, has clearly shown that they are separate, frambœsia being contagious, verruga not; frambœsia beginning with an initial lesion, verruga not; frambœsia being due to *Treponema pertenue* Castellani, verruga not. We may therefore conclude that verruga peruviana is a definite pathological entity.

Climatology.—Verruga peruviana is confined to South America, and to the western slopes of the Andes in Ecuador, Peru, Bolivia, and the northern parts of Chili, the most important endemic area being Peru, where it is almost limited to the departments of Ancachs and Lima, lying north and south of the tenth parallel, and on the western side of the Andes. The department of Ancachs comprises seven provinces, of which the provinces of Pallusca, Huaylas, Huaraz, and Cajatambo, which are on the western slopes of the Andes, are most affected, while that of Santa, which runs along the littoral, is almost free. The disease is, however, peculiarly limited to certain places in these provinces. The heights of these places vary from Cochas, in the province of Cajatambo, which is only at an elevation of 406 metres, to Cajatambo, in the same province, which is at an altitude of 3,350 metres.

One striking peculiarity common to all the places is that they are in narrow valleys along tributaries of rivers. The principal infected areas are Tablachaca, Pallusca, Corongo, Pacatqui, and Ninabamba, in Pallasca; Huaylas and Caráz, in Huaylas; Yautan, Pariacoto Rurasca, Nanca, Jangas, Pongor, Anta, and another district on a branch of the River Huarmey, in Huaraz; Cochas, Huaylillas, and Cajatambo, in Cajatambo.

In the department of Lima there are six provinces, of which Chancay, Canta, Huarochiri, and Yauyos possess endemic areas, which vary in height from 900 to 2,030 metres. In Chancay there is Huaÿcho; in Canta, Acos, Viscas, Yasu, Magdalena, and Yangas; in Huarochiri, Santa Eulalia, Palle, San Gerónimo, San Pedro de Casta, Surco, Cocachacra, Santa Ana, and Sisicaya; and in Yauyos, Omas.

The best-known area is that which lies along the railway from Lima to Oroya, which begins a little below the division of the River Rimac into the rivers Santa Eulalia and Cocachacra, along both of which the disease is endemic for some distance, including Santa Eulalia, San Gerónimo, Chaclla, Cupichi, San Pedro de Casta, San Pedro de Mama, Santa Ana, Corcona Cocachacra, San Bartolomé (where the stream which runs into the Cocachacra River is called the Aqua de Verrugas, because the people believed the disease came from drinking the water), Cuesta Blanca, and Surco.

Here again, as in the department of Ancachs, the disease is restricted to certain deep, narrow valleys, locally known as 'quebradas,' along which streams flow, and which are some 28 to 60 kilometres distant from the littoral, where the disease never occurs.

Ætiology.—The causation of verruga peruviana is quite unknown. Popularly the disease is believed to be conveyed by the drinking-water, which, however, has long been discredited. In 1875 Pancorvo, taking into consideration the well-known fact that the persons who mostly suffer are people who work in the fields or disturb earth, suggested that it was an intoxication due to sulphuretted hydrogen liberated from the earth, a view which never received any marked support. Odriozola and Tamayo have failed to find any bacteria in people suffering from the eruption of Peruvian wart. It is said to occur in animals, especially quadrupeds, and not to be contagious. Chastang believes that some germ is inoculated by the thorns of *Cactus opuntia*. Long ago Raymondi suggested that verruga would, like rabies and syphilis, be found some day to be due to a definite virus. Translating Raymondi's views into modern thought, it would mean that the three diseases would be found to be due to a parasitic protozoon, and, indeed, there is no doubt about the truth of this with regard to syphilis, and with regard to rabies, and it is quite possible that verruga peruviana will some day be found to be of protozoan origin, thus confirming Raymondi's striking conjecture.

The study of the distribution of the disease in the various provinces of Peru, as detailed above, with the aid of a large scale-map, will impress the reader with the similarity to the distribution of Rocky Mountain fever, and will lead him to the conclusion that the ætiological cause must in some way be associated with some blood-sucking animal, perhaps an arachnid; and, indeed, this is supported by a fact well known—that the persons most prone to the infection are those who work in the fields. Such ideas must, however, be taken as mere suggestions, as at present there is no direct evidence in favour of them.

Age, sex, and race appear to have no influence, though it has been asserted that the coloured races have a partial immunity, which may, of course, be due to mild attacks, for, as a rule, an attack confers a lasting immunity.

Pathology.—As the causation is quite unknown, the account of the pathology must be limited to very few remarks. There appears to be no doubt that verruga can be transmitted to animals by inoculation, for Odriozola relates that he inoculated a bitch with the blood from verruga lesions obtained from a post-mortem, with the result that the animal developed a typical skin eruption, and eventually died. The disease is said to occur naturally among animals—*e.g.*, horses, mules, asses, dogs, and fowls—but especially among quadrupeds. The infection in man begins with a general illness, which would appear from the fever, the anæmia, and the pains in different parts of the body, to be of the character of a septicæmia, after which the typical eruption appears on the skin, mucous membranes, and internal organs, when as a rule the general symptoms of fever, etc., abate, from which one would infer that the organism had left the blood-stream, and become located in the skin and other organs. It is possible that it leaves the body by way of the skin. If, however, the local lesion develops in such places as the meninges, the choroid plexus, the choroid coat of the eye, the intestines, the œsophagus, or larynx, severe symptoms are apt to appear, and complicate the illness. If at the same time a paratyphoid-like infection takes place during the febrile stage, the true symptoms are masked, and a peculiar and very deadly type of fever, called ‘ Carrion’s disease,’ or ‘ Oroya fever,’ is produced.

The morbid anatomy is characterized by marked pallor of the body, œdema and dropsy, hypostasis of the lungs, enlargement of the liver and spleen, and hyperæmia of the bone-marrow ; but apart from these general signs, the characteristic features are the appearance of the verrugas in the skin and subcutaneous tissues, in the ocular and palpebral conjunctivæ, the mucosa of the nose, the lips, gums, palate, tongue, pharynx, larynx, trachea, œsophagus, stomach, small and large intestine, in the substance of the liver, spleen, lungs, thymus, thyroid, testicles, kidneys, and lymphatic glands, and at times in the leptomeninges, the choroid plexuses, the choroid coat of the eye, in the substance of the muscles, on the periosteum of bones, on the peritoneal coverings of organs, and on the pleura and pericardium.

The histopathology of the disease has been carefully studied by Biffi and De Veccho. Microscopically a non-ulcerated skin lesion shows the cells of the surface epithelium swollen and distended with glycogen. The papillary layer of the cutis has disappeared, and the dermis proper is infiltrated with round cells, which are mostly mononuclear or polymorphonuclear leucocytes, separated by a slight amount of fibrillar connective tissue, which may in places be entirely absent. There is some doubt as to whether the connective-tissue corpuscles contribute to the round-celled infiltration, as has been asserted by Izquierdo ; in any case, the recognizable connective-tissue cells are always swollen, and their nuclei are altered in various ways. The cellular infiltration is very vascular, and in the case of the older tumours almost cavernous in structure ; hence the liability to hæmorrhage, which is such a marked feature of the disease.

The subcutaneous fatty tissue is always inflamed. In addition to these features, Letulle describes and figures some most peculiar structures seen, under a magnification of 400 diameters, between the cells of the epidermis, which he considers to be clasmatocytes.

The growths appear to be often invaded secondarily with micro-organisms, especially if ulcerated.

Symptomatology.—The incubation period is not definitely known, and is stated to vary from eight to forty days, but to be most usually from twenty to thirty days, during which time prodromata, in the form of malaise, lassitude, and depression, may be experienced.

The invasion is gradual, the prodromal symptoms increasing in virulence, while anæmia becomes apparent, and peculiar rheumatoid pains appear in different parts of the body. These pains are very striking and very misleading, for they may in some cases be limited to a single region, or even to a single joint or muscle ; on the other hand, they may be more extensive, and lead to a diagnosis of some nerve disorder.

As a rule, but not invariably, fever appears, and varies in intensity with the severity of the attack. Usually it is intermittent in character, the paroxysm beginning about noon with chills, severe pains, much thirst, and a rise of temperature to about 104° F., with a quick, soft, compressible pulse, and ending in about twelve hours by crisis, associated with sweating and an amelioration of the pains. The liver and spleen enlarge, and the patient becomes very anæmic and feeble, and usually constipated, but may at times suffer from diarrhœa. This is the stage during which Carrion's fever develops, the temperature becoming almost continuous, the pains and the diarrhœa severe, the urine dark and scanty, acid in reaction, with high specific gravity, increased indican, but rarely albumin, and contains something which reduces Fehling's solution ; the anæmia becomes profound ; nucleated red cells appearing, while death results in about two to three weeks.

This severe fever is probably a complication with a variety of paratyphoid, as already mentioned, and ends fatally before the typical eruption appears.

In milder cases, after the febrile stage has lasted from twenty days to eight months, the skin begins to itch, and an eruption appears on the face, neck, the extensor surfaces of the arms and legs, and at times on the conjunctivæ, the lips, tongue, gums, palate, and pharynx. This eruption shows itself at first as small, pinkish-red, erythematous spots, sometimes associated with small vesicles, or more rarely with bullæ or pustules.

The erythematous areas speedily become papules, and finally tubercles, which may vary in size and in number. The usual size is about that of a pea.

When fully developed, they appear as elevated, cylindrical, fungiform, or irregular wart-like bodies, usually discrete, red in colour, generally firm to the touch (though they may be soft), and very liable to bleed. This type of eruption is the *forme miliare* of the Odriozolas and Salazar. In addition to these superficial tubercles there are deep subcutaneous nodules, which lie under the unaltered skin, and from which at first they are quite free. These nodules may reach a large size, and become adherent to the skin, ulcerate, and reach the surface as large red fungating masses, which readily bleed. This is the *forme mulaire* of the above-mentioned authors.

The area of the skin on which the spots appear is usually œdematous, a feature most commonly observed on the legs. With the appearance of the eruption the fever declines, the general symptoms abate, and the patient feels better, but the blood shows a marked diminution in the red cells, some of which are nucleated, and a corresponding reduction in the hæmoglobin, and this anæmia may be aggravated by hæmorrhages from the tubercles, which may be so severe as to cause the death of the patient. At this stage the verrugas may develop in the internal organs, and cause serious symptoms: thus in the larynx they will cause dyspnœa; in the bronchi, bronchitis; in the lungs, pneumonia; in the pleura, pleurisy; in the nose, epistaxis and difficulty in nasal breathing; in the œsophagus, dysphagia; in the intestine, bloody diarrhœa; in the meninges, brain symptoms; in the eye, amblyopia; and in the uterus, metrorrhagia.

After lasting from four to six months, during which several crops appear and disappear, each preceded by an attack of fever, the eruption finally disappears, and the nodules, becoming pale and drying up, disappear without producing a scar, while the ulcerated nodules dry up and heal by cicatrization, and the patient is left convalescent, but anæmic and feeble.

The course of the disease, however, is by no means as straightforward as depicted, for at times the eruption comes out poorly, and is limited in its distribution, or, having developed, may disappear, in which cases the general symptoms, which may have improved, are apt to return and cause a serious illness.

Varieties.—Slight cases may pass through the whole illness without fever, while more severe cases show intermittent or even remittent fever.

Complications.—The complications are numerous, and include septic poisoning, malaria, tuberculosis, and syphilis, but the most severe is that with Barton's bacillus, the probable cause of Carrion's fever.

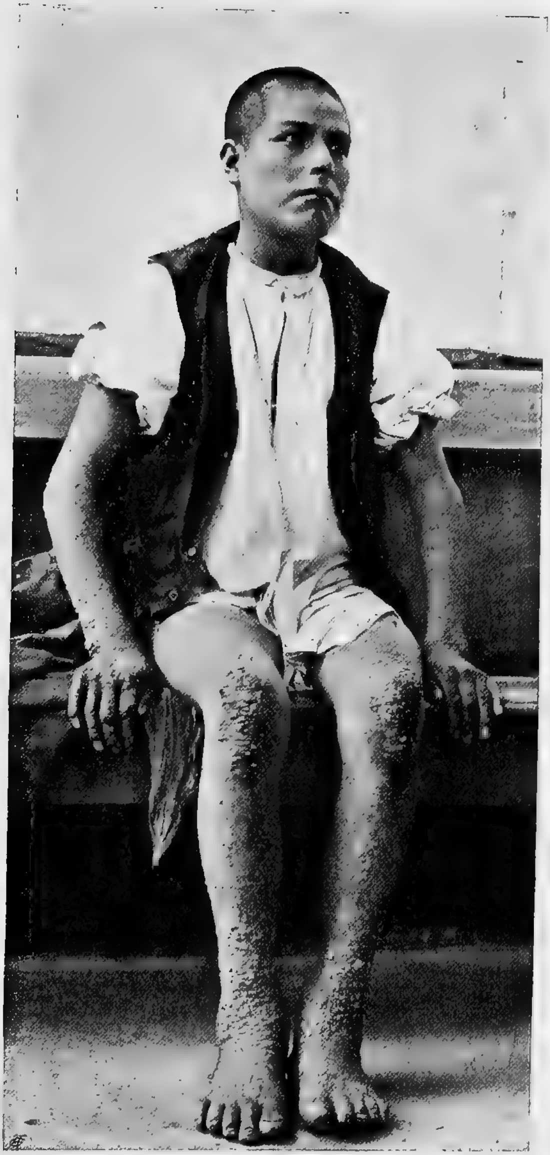

Fig. 328.—Verruga Peruviana: Eruption on Extremities. (After Biffi, from the *Archiv für Schiffs- u. Tropenhygiene.*)

Sequelæ.—The usual sequelæ are anæmia, dropsy, and affections of the nervous system.

Diagnosis.—The most important feature in the diagnosis is residence in one of the endemic areas, when a person complaining of vague pains and illness, with distinct anæmia, with or without febrile symptoms, should be regarded as most likely to be suffering from verruga. The febrile stage must be differentiated from malaria by the absence of the parasites in the blood, from typhoid by the serum reactions, from tuberculosis by skin and ophthalmic reaction, from rheumatism by the absence of the swelling of the joints, and from histoplasmosis by the absence of the parasite. The stage of eruption must be distinguished from frambœsia by the absence of the eruption on the trunk, by the tendency to hæmorrhage, and the absence of *Treponema pertenue.*

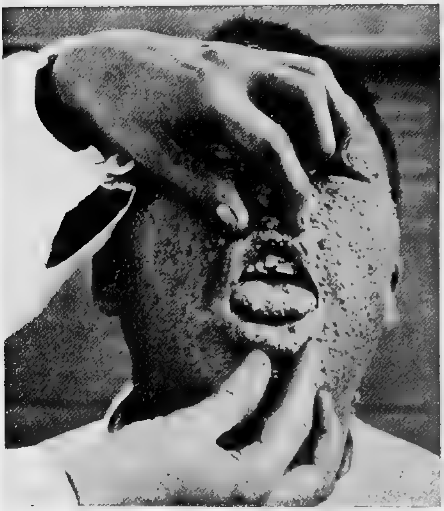

FIG. 329.—VERRUGA PERUVIANA: ERUPTION ON THE FACE, LIPS, AND TONGUE.
(After Biffi, from the *Archiv für Schiffs- u. Tropenhygiene.*)

Prognosis.—With the possibility of such a serious complication as Carrion's fever arising, or in later stages of internal verrugas forming, the prognosis must be very guarded. A good sign is an early appearance of a widely-spread eruption, while a poorly-developed eruption associated with anæmia and marked weakness is of grave import.

Especially serious is the disappearance of a poorly-marked eruption, and the reappearance of fever pains, etc. Cold weather and high altitudes are unfavourable, and complications increase the gravity of the case considerably, the former because it delays the development of the eruption and may cause it to abort, and the latter because it increases the tendency to hæmorrhage. The mortality varies from 10 to 40 per cent.

Treatment.—No specific treatment is known, but Odriozola recommends hypodermic injections of arsenic (probably atoxyl would be found useful), and removal from the endemic region to the warm countries along the littoral will also be of benefit. Chills and cold baths must be specially avoided as being apt to stop the development of the eruption, and hence to endanger the life of the patient. Drugs appear to be useless in the febrile stage, and though decoctions of maize, of *Buttneria cordata* (Buttneriaceæ), *Budleja incana* (Scrofulariaceæ), or *Schinus molle* (Terebenthinaceæ), have been popular, they are now believed to be useless.

Tonics of iron and arsenic are useful during convalescence, but the iron is best administered by hypodermic injections. Carrion's fever must be treated in the same manner as typhoid fever.

Prophylaxis.—In the present state of our knowledge the only possible prophylaxis is to avoid the endemic regions.

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There are numerous references in the 'Cronica Medica,' published in Lima, but the most important monograph is that by E. Odriozola, which is excellently illustrated with maps and coloured plates, and in which the subject is treated in the fullest manner.

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CHAPTER XXXIX

BERI-BERI AND EPIDEMIC DROPSY

Beri-Beri—Epidemic Dropsy.

BERI-BERI.

Synonyms.—Polyneuritis Endemica, Neuritis Multiplex Endemica, Hydrops Asthmaticus, Synclonus Beriberia, Myelopathia Tropica Scorbutica, Paraplegia Mephitica, Sero-phthisis Perniciosa Endemica, Panneuritis Endemica, Berbiers, Kakké (signifying a disease of the legs in Japan and China), Loempoe (Java), Kaki-lem-but, Hinchazon de los Negros y Chinos, Maladie des Sucreries (French Antilles), Hinchazon (Cuba), Inchaçao, or Perneiras (Brazil).

Etymology.—The word 'beri-beri' is said to be derived from the Sinhalese term, meaning 'cannot,' which is used as a phrase, which means 'I cannot,' employed in the sense that the person is too ill to do anything. There is another Sinhalese word which may equally be translated as 'cannot,' but this means that the person is unwilling to do something, not that he is too ill to do it. It is possible that the above interpretation of the word is correct, for Ceylon has long been in the hands of Europeans—*e.g.*, Portuguese, Dutch, and English—and therefore a term used therein would be widespread. There is no doubt that the word covered a large number of diseases, from which a definite pathological entity has gradually been separated out. It is to be noted, however, that—at all events, at the present time—the disease does not exist endemically in Ceylon, where there are only imported cases.

Definition.—Beri-beri is an acute or chronic, endemic or epidemic, disease, of unknown causation, which is characterized by degeneration of many peripheral nerves, especially the vagi, the phrenics, and those of the limbs, associated with gastro-intestinal disturbance, cardiac disturbance, and œdema.

History.—According to Scheube, it is possible that the first mention of beri-beri is to be found in the accounts given by Strabo and Dio Cassius of a disease which attacked a Roman army in 24 B.C. in Arabia. Kakké is also mentioned in a Chinese pamphlet belonging to the second century of the present era, and is minutely described in another belonging to the seventh century, while it is recorded as occurring in Japan in the ninth century. In the tenth century a distinction was made between the atrophic, dry or paralytic, and the hypertrophic, wet, or dropsical forms of the complaint.

In 1758-59 Bontius was the first European doctor to give an account of the disease, which he described under the term ‘ beri-beri.’ Later, Tulpius, a Dutch physician, also described the symptoms of the disease as seen in a person who had returned to Holland from the Indies. From that time the literature on beri-beri has grown until it has reached enormous proportions, but unfortunately there is no doubt that until recently several diseases, especially agchylostomiasis and epidemic dropsy, were confounded with it. Rogers in 1808, and later Davy, describe the disease as ‘ beri-beria,’ while the latter says that it is almost peculiar to Ceylon.

In 1847 Carter gave a description of the disease, indicating asthma as the principal feature, probably because of the cardiac dyspnœa. In 1873 Fayrer laid great stress on œdema as the important clinical feature. In 1877 Wernich defined the disease kakké in Japan, while Van Meedervoort showed that it was the same disease as beri-beri. In 1886 Kynsey published an account of the anæmia or beri-beri of Ceylon, by which he really meant agchylostomiasis; hence the idea that beri-beri was due to *Agchylostomum duodenale*, and hence the large number of cases of so-called beri-beri in Ceylon years ago.

The scientific and clinical study of the disease has been largely due to the work of Oudenhoven, Da Sylva Lima, Overbeck de Rieyer, Baelz, Scheube, Pekelhäring and Winkler, Hamilton Wright, and Fraser and Stanton. The workers on the ætiology of the disease are so numerous that this part of the history is best treated in the section on the causation.

Beri-beri is in certain regions a most serious disease. Thus Braddon says that in the Straits Settlements and Malaya, where the population is only 1,250,000, no less than 150,000 cases of the disease, with 30,000 deaths, have occurred in Government hospitals and infirmaries in the last twenty years; but he says that only one-third of the deaths of Chinese took place in those hospitals, and therefore the total deaths in that period would be about 100,000. It is also a great element in inefficiency, for it is reckoned that 33 per cent. of the sailors of the Japanese Navy prior to 1884 were continuously disabled by it. In 1904-05 it is said that 24 per cent. of the entire sick and wounded in the Japanese armies—*i.e.*, about 85,000 men—were also disabled by it. It is obvious, therefore, that the disease is of great medical and economic interest, for its incidence particularly falls upon the labourer, the sailor, the soldier, and the prisoners in the gaols, and hence hampers both the employer of labour and the Government. Braddon estimates the cost of the disease to the Government of Malaya as £10,000 per annum in direct hospital charges only.

Climatology.—The endemic centre of beri-beri appears to be Eastern Asia, Japan, China, the Philippine Islands, Indo-China, Java, and Malaya. It is also said to occur in Brazil and, according to Plehn, in Réunion, Mauritius, Nossi-bé, Zanzibar, Cape Colony, Senegal, Angola, the Congo Free State, and the Cameroons. We have met with the disease on the Gold Coast in Chinese miners, but have not noted it in the native population, though it may possibly exist. Isolated epidemics, sporadic or imported cases, occur in England, Ireland, and other parts of Europe, the United States, Canada, and in Ceylon. In the last-named place it is now almost entirely absent, and, indeed, it is possible that many of the cases reported years ago may have been agchylostomiasis or some other disease. Imported cases from India and China are frequently met with in Colombo, owing to its possessing a large harbour where numerous vessels, with Chinese and Indian crews, call.

It is believed that the Bihimbo disease of the Chaka district of Uganda is beri-beri. In the tropics it is said to occur more often in the cool wet months.

Ætiology.—The causation of beri-beri is quite unknown, but, as may be imagined in such a widespread and fatal disorder, the investigators have been many, and hence the theories are legion. In order to comprehend the present state of the question, it is necessary very briefly to review a few of these theories, which will be best done by following a method of classification.

A. Physical Cause.—The older writers, like Davy, considered that it was brought about by some unusual state of the atmosphere, but they said, honestly, that this was merely a cloak for their ignorance of the true cause.

B. Chemical Causes.—The chemical causes which have been advanced are:

1. Arsenical poisoning (Ross).
2. Oxalate poisoning (Treutlein).
3. Carbon dioxide poisoning (Ashmead).
4. Food poisoning—
    (*a*) Ichthyotoxismus (Grimm and Miura).
    (*b*) Sitotoxismus (Eijkman, Vorderman, Yamagiwa, Van Dieren); rice (Gelpke, Braddon, Fraser and Stanton); lathyrism (Le Roy de Méricourt).
5. Some deficiency in the food—
    (*a*) Deficient nitrogen (Takaki).
    (*b*) Deficient fat (Brémaud and Laurent).
    (*c*) Deficient vegetables, together with an infection (Fales).
6. An intoxication from a germ living outside the body (Manson).
7. An intoxication or an auto-intoxication (Duerck).

1. Arsenical Poisoning.—Ross, in 1900 and subsequent years, drew attention to the similarity between beri-beri and the arsenical poisoning which at that time was prevalent throughout Lancashire, being brought about through the agency of arsenical beer. He further supported this by finding arsenic in the hair in recent, but not in old, cases of the disease in Penang, and woke up a controversy as to whether arsenic existed in normal hair or not. But apart from the obvious reasons against this theory as an explanation for such a widespread disease, Herzog has definitely shown that no arsenic could be found in the hair of ten cases of different types of the disease. There is no doubt that cases of chronic arsenical poisoning do occur in the tropics, as we have seen, particularly in Europeans who have had to live for a long time on tinned food, but these cases are not beri-beri.

2. OXALATE POISONING.—The oxalate theory is based upon the fact that Maurer and Treutlein were able to produce a condition resembling beri-beri in fowls by giving them oxalic acid in their food. The latter observer considered that the acid removed the calcium salts from the body of these animals, and caused thereby a degeneration of the peripheral nerves and heart muscle, and considered that this was proved by curing them by the administration of calcium salts. Further, he showed that there was an excessive excretion of calcium in the urine of beri-beri patients. But polyneuritis has been produced in fowls by Eijkman by feeding them with cooked rice, and it is possible that neither oxalic acid nor rice, but an infection, was the cause of the disease, which may, of course, be quite different from true beri-beri.

3. CARBON DIOXIDE POISONING.—Ashmead believes that the disease is caused by the excessive inhalation of carbon dioxide, but outbreaks occur without any overcrowding, as we have seen ourselves.

4. FOOD POISONING.—(*a*) *Ichthyotoxismus.*—Grimm considers the ingestion of raw fish to be the cause of the disease, and Miura the consumption of species of the Scombridæ; but Wright has shown that in the gaol at Kwala Lumpur the disease infected forty-nine prisoners when no fish had been given for eight months.

(*b*) *Sitotoxismus.*—Rice poisoning at present is the favourite theory, and has had many supporters. Thus Eijkman and Vorderman consider that it is due to eating rice without husk, which is the natural protection. Gelpke considers that it is due to stale or badly-kept rice. Yamagiwa considers it due to rice improperly stored and preserved, as it occurs even when this rice is well boiled. Braddon, who is often wrongly quoted, ascribes the disease to the ingestion of a *poison* found in the rice, which is the result of the specific product of some organism—epiphyte or parasite—but he does not believe that the disease is due to the ingestion of the organism. Contrary to Eijkman and Vorderman, Braddon looks upon the husk as the dangerous element, as it is in this that the germ grows.

But the disease has been observed, according to Scheube, who quotes Fiebig and Voorthnis, in Brazil, the Moluccas and Liugga, where the people live on sago, fish, and game, and where the attacked Europeans had never eaten rice.

Travers details an interesting observation on this point concerning an epidemic of beri-beri in the Pudoh Gaol of Kwala Lumpur, in August, 1895, when some of the cases were transferred to the Old Gaol, one and a half miles distant, on October 1, 1895, because the mortality in the Pudoh Gaol was extremely high; and on October 25, 1895, sixty prisoners, showing no signs of the disease, and apparently in good health, were similarly transferred. From October 1 to December 14, 1895, all food supplied to the healthy prisoners in the Old Gaol, as well as to the beri-beri patients transferred from the Pudoh Gaol, was cooked in the Pudoh Gaol with the food for the other prisoners who were suffering from the disease.

This food was carried to the Old Gaol twice daily, and the diet was exactly the same in both gaols, the rice being taken out of the same bag and cooked in the same steamer. Further, it appears from Braddon's remarks that in 1895 a new scale of ordinary diets, with an increased amount of rice, was allowed, fresh fish was replaced by salted, and beans were omitted, and Braddon considers that it was this increase of the rice that increased the poison and made the people ill; but this ought to apply to both places.

Moreover, Braddon considers deductions adverse to rice in the above experiment to be fallacious, for he holds that the length of period of incarceration of the above prisoners is an important factor; for the liability to acquire the disease, he says, increases with and varies directly according to the length of the time served in prison, which must be more than six months. He points out that it is not stated how many long-sentence prisoners were sent to the Old Gaol, which he thinks may not have been more than two or three; and concerning these, he says, there is no proof that any of them were kept for the period necessary to acquire the disease by rice intoxication. He therefore concludes that Travers' experience affords no ground for opposing the theory that beri-beri is incurred through the consumption of certain sorts of rice. Recently Fraser and Stanton have strongly supported Braddon's rice theory by showing that members of gangs of coolies who had previously remained quite healthy developed beri-beri when fed on white rice, while other members of the same gangs, fed on brown rice, remained healthy. Further, they showed that the disease disappeared when white rice ceased to be used as an article of diet. The isolated position in which the gangs were working almost excluded any possibility of infection from place or from persons, but not quite from the latter.

5. SOME DEFICIENCY IN THE FOOD.—(*a*) *Deficient Nitrogen.*—Previous to 1884, 33 per cent. of the sailors in the Japanese Navy were disabled owing to beri-beri.

In 1883 the *Ryujo*, a Japanese warship, went on a voyage of 271 days to New Zealand and South America, and developed 160 cases of the disease out of a crew of 350 men. Takaki investigated this outbreak, and came to the conclusion that there was too little nitrogen in the diet, the nutritive value of which was: Proteids, 109·29 grammes; fats, 15·8 grammes; carbohydrates, 622·32 grammes. He therefore changed the diet to: Proteids, 196 grammes; fats, 43 grammes; and carbohydrates, 775 grammes; and on this dietary the warship *Taukuba* was sent the same cruise, taking 287 days, and only suffered from sixteen cases of the disease. Takaki attributed the success to the increased nitrogen, a portion of the rice being replaced by corn or bread; but Fales has pointed out that fresh vegetables were increased from 215 grammes to 450 grammes, and that therefore nitrogen alone may not have been the cause of the decrease of the disease. This dietary was applied to the Japanese Army and Navy, and beri-beri decreased enormously. But Baelz has pointed out that this decrease was associated with a great improvement in general hygiene, and that it also took place in barracks in which the food had not been changed. A similar decrease in the Dutch-Indian Navy, associated with a better diet, was attributed by some to the improved hygiene rather than to the diet.

(*b*) *Deficient Fat.*—Brémaud and Laurent believe that the disease is due to too little fat in the food, and consider that an epidemic at Chaudabum, in Siam, was stopped by causing fat to be more freely consumed by the healthy. This theory, however, has found but little support.

(*c*) *Deficient Vegetables, together with an Infection.*—Fales, from a study of an outbreak of an epidemic of beri-beri in the Bilibid prison, in Manila, came to the conclusion that the lack of fresh vegetables conduced powerfully to both beri-beri and scurvy.

In November, 1901, there were two cases of the disease, and no deaths, in that gaol. The food was then changed to a ration consisting of 97·17 grammes of proteids, 17·24 grammes of fats, 491·04 grammes of carbohydrates and 26·52 grammes of salts. In this diet there were 85·05 grammes of potatoes, and 453·60 grammes of rice. Put into other figures, this diet consisted of: Nitrogen, 172·1 grammes; carbon, 4,166·5 grammes; hydrogen, 61·9 grammes; sulphur, 13·2 grammes; salts, 140·2 grammes—the proportion of nitrogen to carbon being as 1 to 24·2. Whereas, calculating the weight of Filipinos at 125 pounds, it was estimated that proteids ought, according to Voigt's diet, to have been at least 94 grammes, fats 45 grammes, and carbohydrates 400 grammes; or, according to Moleshott's diet, nitrogen, 256 grammes; carbon, 3,789 grammes; hydrogen, 143 grammes; sulphur, 23 grammes; salts, 172 grammes—*i.e.*, N : C : : 1 : 0·15.

The epidemic of beri-beri now began: December, 1901, 52 cases and 2 deaths; January, 1902, 169 and 12; February, 1,087 and 16; March, 576 and 15; April, 327 and 15; May, 310 and 19; June, 451 and 17; July, 233 and 33; August, 571 and 24; September, 522 and 31.

On October 20 the diet was again changed, and this time proteids were 101·71 grammes; fats, 19·37 grammes; carbohydrates, 395·73 grammes; salts, 29·13 grammes; including 119·07 grammes of potatoes and 255·15 grammes of rice. Nitrogen was 209·8 grammes; carbon, 3,816·2 grammes; hydrogen, 70·4 grammes; sulphur, 17·2 grammes; and salts, 185 grammes—N : C : : 1 : 13·4.

In October there were 579 cases and 34 deaths; November, 476 and 8; December, 89 and 3; half January, 1903, 4 cases and no deaths.

Along with the beri-beri there was an epidemic of scurvy, and Fales was of the opinion that both diseases were led up to by a deficiency of vegetables, the essential principle of which he believes to be potassium carbonate, of which rice contains only 0·01 grain per ounce, while potatoes contain 1·875 grains. Hence, according to Fales, the disappearance of the disease when a sufficiency of vegetables, especially potatoes, was given. But he says this deficiency is only a predisposing cause, which enables the micro-organism, whatever it is, which is the true cause of the disease, to flourish and produce the symptoms. In other words, the people get run down by a bad diet, and are ready for any disease, so that this does not clear up the ætiology.

Recently Ingram has drawn attention to an outbreak in the 81st Pioneers and the 2nd Battalion of the King's Own Scottish Borderers, at Aden, in which he could find no clear evidence that beri-beri was due to diet alone, whether insufficient proteids or excessive rice, or bad rice, but he considered a diet rich in proteids good as a preventative. He could only find one thing in common in the two regiments—viz., both brought the disease with them—but was unable to find any source of infection, parasitic or otherwise.

6. An Intoxication from a Germ living outside the Body.—Manson brought forward the hypothesis that a germ may live in the soil, the house, or the ship occupied by the human being, under certain conditions of temperature and moisture, and may grow and produce some kind of toxin which, being inhaled or swallowed, or otherwise introduced, causes the disease. Moreover, this germ may be carried by men from place to place.

He supports this theory by pointing out—(1) that when patients are removed from an endemic spot they at once begin to recover; (2) he quotes Hirota's observation that fifty-two infants nursed by beri-beric mothers showed signs of the disease, and did not improve when treated medicinally, but rapidly improved, if the disease had not advanced too far, when taken from these mothers and placed on artificial food or given to a healthy wet-nurse. Further, Herzog says that, according to Dr. Albert, similar cases are not very infrequent in the Philippine Islands, but the removal of the child from the mother is most difficult, as the people do not understand the necessity.

Manson rightly points out that these children must have been poisoned with some chemical substance, and not infected with a germ. But, of course, the germ causing the toxin might be in the mother's body.

Again, Manson points out that the disease clings to ships, in which it appears year after year when the tropics are reached. There is also evidence that the cause, whatever it is, clings to rooms for a short time.

7. An Intoxication or an Auto-Intoxication.—Duerck is convinced from the study of the pathology that the cause of the disease is a toxæmia, and points out that substances formed in the body by process of auto-intoxication may produce peripheral neuritis, but the epidemics of the disease are quite against a theory of auto-intoxication.

C. Biological Causes.—A great many observers are in favour of a biological cause for the disease, without committing themselves as to whether it is animal or vegetal. Among these may be mentioned Sambon, who considers that the specific agent lives in the patient's body. Scheube considers that it is an infectious, but not a contagious, disease, and says that the analogy with malaria is in some respects striking, and that it is spread by mechanical transmission of the disease by human intercourse in some way or another. This is quite true, because there are numerous instances of disease being imported by human beings into a fresh place and spreading, but the curious point is that it generally sticks to one race.

Thus, in Malaya it is a common disease among imported Chinese, and hardly known among the natives. In the Bilibid Prison, mentioned above, the prisoners included Filipinos, Spaniards, Chinese, Japanese, Indians, American negroes, Americans, and Europeans, but the disease fell most severely on the Filipinos, the Chinese being almost exempt, only one or two contracting the disease, while the Americans were immune. Van der Scheer suggested that perhaps insects, such as cockroaches, might be the spreaders of the disease, but Durham's investigations are contrary to this. It would seem as though the causal agent was spread by some parasite, for Daniels has carefully considered the question of infection, and does not find any evidence in favour of it being conveyed by the excreta of persons suffering from the disease, especially the fæces.

Further, he points out that infection by air and water can be excluded, as in Kwala Lumpur all races drink the same water, but only Chinese are attacked, even though they drink little unboiled water; and the immunity of prison officials from the disease while an epidemic rages among the prisoners excludes air. Disinfection appears, from Durham's results on Christmas Island, to be useless. As regards parasites, Durham and Daniels are both against mosquitoes as being the cause—and, indeed, this is hardly likely—and also against bugs.

On the other hand, there appears to be some evidence in favour of *Pediculus capitis*, which is apt to cling to one race, and this is, according to Daniels, a plausible theory in explaining the racial selection of the disease. Experiments on an orang-outang with pediculi from a beri-beri case were negative, the lice rapidly disappearing. Daniels could not exclude fomites as a carrier of the disease in his observations. Only one observer, Taylor, is said to have produced the disease in animals by the inoculation of the blood from patients. Having thus briefly considered the general question of contagium vivum, and its method of entry into the body, it is necessary to review the various organisms which have been held to be the cause of the disease.

They may be classified into:

ANIMAL CAUSES:

(*a*) *Protozoa.*
1. Plasmodium in the blood (Glogner).
2. Protozoon in the urine (Hewlett and Korté).
3. Hæmatozoa in the blood (Fajardo and Voorthuis).

(*b*) *Nemathelminthes.*
1. Some form of *Trichinella* (Gelpke).
2. *Trichuris trichiura* (Erni and Kynsey).
3. *Agchylostoma duodenale* (Erni and Kynsey).

VEGETAL CAUSES—FUNGI:

(*a*) *Coccaceæ.*
1. Cocci in the alimentary canal, etc. (Dangerfield).
2. Diplococcus in the urine (Tsuzuki).
3. Diplococcus from the blood and urine or organs post mortem (Okata and Kokubo).
4. Four kinds of cocci (Musso and Morelli).

(*b*) *Coccus and Bacillus.*
Pleomorphic organism obtained by Pekelhāring and Winckler from the blood.
Bacilli and cocci by Lacerda.

(*c*) *Bacilli.*
1. Bacillus by Taylor.
2. Bacillus by Rost.
3. Bacillus by Ogata.
4. Three kinds of bacilli by Nepveu.
5. Bacillus by Eccke.

Toxins from a bacillus in the alimentary canal (Hamilton Wright).

(*d*) *Fungi higher than Bacteria.*
Mouldy rice (Hose).

Protozoa.—Glogner's parasites were similar to malarial parasites, but were distinguished therefrom by being found only in splenic blood, by being always extracorpuscular, and by increasing by gemmation. They were more pigmented than malarial parasites. Scheube thinks that Glogner's cases were complications of beri-beri with malaria.

Hewlett and Korté centrifugalized the urine of beri-beri cases, and found small refractile spherical bodies, 2 to 3 μ in diameter, with a thick capsule and hyaline contents; others 20 μ in diameter, with a cytoplasm studded with refractile granules, and containing a single nucleus; and others 30 μ, with a thick capsule, an oval nucleus, and a rounded nucleolus. They further described the congestion of the glomerular vessels and hæmorrhages into the tubules of the kidney. Further, they saw a somewhat similar disease in monkeys, the urine of which contained highly refracted cells. They conclude that the above are either peculiar degenerate cells or protozoa, and suggest that the disease is a protozoan infection, and that the causal agent is eliminated by the urine. Fijardo and Voorthuis separately describe hæmatozoa, partly free and partly in the red cells, which are similar to, but not identical with, the malarial parasites. Their organisms do not agree with one another, nor do they correspond to Glogner's.

Nemathelminthes.—Gelpke suggested that the disease might be due to a *Trichinella* in fish, but he has withdrawn this. *Trichiuris* and *Agchylostoma* need not seriously be considered, as this idea arose from a misunderstanding.

Fungi.—Pekelhäring and Winckler's bacillus has also been found by Hunter, and experimental inoculations by both sets of observers produced degenerations of the nerves. But it must be admitted with regard to bacteria that competent observers have found the blood sterile time after time.

Hamilton Wright's bacillus, which occurs in the alimentary canal, has been found by Dudgeon to be non-pathogenic for monkeys, and not to be agglutinated by the blood of beri-beri patients. Stanley's experiments on animals with mouldy rice have been negative. Finally, attention may be drawn to the researches of Holst, Nocht, and the Norwegian Ship Beri-beri Committee, which indicate that the so-called ship beri-beri is not beri-beri, as the symptoms are shortness of breath and weak heart, with weakness and dropsy of the lower limbs, but not paralysis of the limbs—*i.e.*, the degeneration of the nerves is not an essential phenomenon. In conclusion, we are bound to state that the ætiology of the disease is unknown, and that we, personally, are inclined to consider the disease to be of protozoan origin.

Predisposing Causes.—The disease can occur in all races, and at all ages, and in both sexes, but it is apt to cling particularly to one race in a country—*e.g.*, the Chinese in Malaya, the Filipinos in the Philippine gaol outbreak. This racial incidence is most marked. Thus, Braddon says that of the Chinese immigrants into the Straits and Malaya, it may be reckoned that of every 1,000 living, 120 suffer and 16 die of the disease. The Malayas are said to suffer but little, if at all. In the Bilibid Prison in Manila, on the other hand, according to Fales, the Filipinos suffered most severely, the Chinese were almost exempt, only one or two contracting the disease, while the Americans were entirely free.

With regard to age, it is most commonly met with in young adults between fifteen and thirty years, but it has also been noted in babies at the breast and in old men. It is more commonly met with in men than in women.

Recently occupation has been carefully investigated by Hunter and Koch in Hong-Kong, and they conclude that the disease is universally present throughout the community, but especially affects the working classes, while the professions, the merchants, and the leisured classes are practically, but not entirely, exempt.

Other predisposing causes are disturbance of the soil and a high atmospheric temperature.

Important Features.—The peculiar features of the disease are that, though it generally occurs among rice-eating peoples, yet at times it occurs in other communities, as in the British regiment, in whose ration there was but a small quantity of rice, which was cured Rangoon rice, while Braddon says 'those who eat only cured rice never get it.' Finally, if observers are to be trusted, there are places where beri-beri occurs and rice is not eaten. On the other hand, there is a great deal of evidence in support of the idea that one case in some way or another leads to others, who mostly belong to the same race or occupation—*i.e.*, that the disease is in some way infectious, and is spread by the agency of man. Daniel's idea of a pediculus, though there is no definite support at present, deserves serious consideration.

To summarize from the evidence, it appears more likely that a parasite will be found to be the spreader of the disease, which makes it more probable that the actual cause will be found to be a protozoon than that it is due to diet, which, however, may be a predisposing cause, especially if the nutritive value of the food is low, or the proportions wrong.

Pathology.—As the cause of the disease is unknown, but little can be said as to the pathology, but Mott and Halliburton have performed an experiment which throws much light on the disease. They injected blood taken from an acute case of beri-beri into a cat, and found a fall of blood-pressure, with dilatation of the vessels of the stomach, intestines, and liver, as well as general venous engorgement, and they also noted dilatation of the right side of the heart, and microscopical hæmorrhages into the liver. This would clearly indicate that a poison capable of producing great vaso-motor changes was circulating in the blood of beri-beri patients. In addition to the engorgements found in the cat, the human being suffers from congestion of the pharynx, and degeneration of the cardiac, muscular, and sensory nerves. The œdema is probably due to the vaso-motor disturbance.

Durham considers that the urine indicates a serious diminution of the metabolism.

Morbid Anatomy.—The morbid anatomy and histo-pathology have been studied by numerous observers, among whom the investigations of Wright, Dürck, and Scheube must be especially mentioned. In acute cases there is always some œdema, but at times this may be excessive, and the veins of the neck are swollen. Hypostasis is always well marked, but may be excessive, especially about the face. There is often froth at the mouth. In chronic cases the body is pale, and may be swollen with dropsy or emaciated. In the former the post-mortem rigidity develops quickly, and is well marked. In the latter, however, it is not so marked. On cutting into the body the subcutaneous tissues are usually œdematous, and the veins are filled with dark fluid blood. There is a varying quantity of serous fluid in the abdomen, the chest, and the pericardium, and there may be petechial hæmorrhages under the visceral pleura, and pericardium in acute, but not in chronic, cases. The throat and tonsils are generally congested in acute cases, but they may be normal; the larynx may be congested or normal. The mucosa of the trachea and bronchi may be œdematous, with the lumen full of fluid. The lungs may be congested and œdematous, and may contain little air.

The right side of the heart is always greatly dilated in acute cases, and is also hypertrophied in older cases, but it is rare for the left ventricle to be hypertrophied, though it may be dilated to a moderate extent. The myocardium generally shows fatty degeneration, the striation is often absent, and segmentation and vacuolation of the fibres, with an increase of the interstitial tissue, can also be seen, and there is a round-celled infiltration beneath both endo- and epicardium in acute cases. (These changes are said by Scheube to be like those found in rabbits after section of both vagi.)

According to Wright, the entire nervous system of the heart is damaged in acute cases, the cells of the bulbar nuclei and the nucleus ambiguus on both sides being swollen, with excentrically placed nuclei and a disappearance of Nissl's bodies in the processes, and to a less extent at the periphery. These changes may also be seen in the first and second pair of the thoracic ganglia, and in the intrinsic ganglionic cells of the heart, while the vagal nerve-endings show rounded droplets of altered myelin (neurokeratin ?), especially near the nodes. In chronic cases only the vagi may show degeneration, the ganglia in the heart being normal.

In acute cases the stomach and duodenum are markedly affected, the mucosa being hyperæmic, with more or less marked hæmorrhagic extravasations, and even at times effusion of blood into the lumen of the viscus. This inflammation may extend to the ileum, or very rarely even to the cæcum, but usually the small and large intestines show nothing abnormal, for the acute irritation is located to the pylorus and the duodenum.

Microscopically there is an acute congestion with round-celled infiltration, with, according to Herzog, a very large number of eosinophile cells and necrosis of the glandular epithelium. The cells of Auerbach and Meissner's plexuses are degenerate, and the nerve fibres in the stomach and duodenum also show signs of degeneration. In chronic beri-beri these gastro-duodenal signs are absent.

In an acute case the lymphatic glands near the stomach and duodenum are enlarged and congested. The liver is generally enlarged and congested, and at times in a nutmeg-like condition, and, according to Hewlett and Korté, there may be extensive hæmorrhagic patches. Scheube and Plehn draw attention to a round-celled infiltration of the interlobular connective tissue, which the latter calls a beri-beric interstitial hepatitis. The cells show fatty degeneration, cloudy swelling, and at times necrosis. The spleen may show some cyanosis, and be slightly enlarged and indurated, but usually it is normal. The wall of the gall-bladder may be œdematous at times; the pancreas is normal. The suprarenals may be pigmented and congested with vacuolated cells. The kidneys are usually swollen and hyperæmic, and there may be hæmorrhages into the glomeruli, tubules, and pelvis, together with cloudy swelling and cellular infiltration. The ureters and bladder are usually normal.

The nervous system is markedly affected. The meninges of the brain may be hyperæmic, and there may be some hyperæmia of the brain substance itself, and increase of fluid in the ventricles, but the microscope shows nothing abnormal except in the bulb, where, according to Wright, there are the changes already mentioned in the vagal nucleus. Kustermann also describes acute degeneration of the vagal ganglia at the base of the fourth ventricle.

The spinal cord is usually normal. Hamilton Wright and others have described degeneration of the cells of the posterior spinal ganglia and anterior cornua of the lumbar cord, together with atrophy of Goll's column, in which histologically there is a thickening of the glia tissue and a complete disappearance of the nerve fibres, with the presence of many granular cells.

The peripheral nerves are usually normal to the naked eye, but may be injected and hæmorrhagic. Scheube and Baelz first showed that these nerves were degenerated, the muscular branches of the nerves of the limbs being most affected, but even the fine sensory cutaneous branches were also attacked. The changes in the autonomic nervous system do not appear to have been closely studied, though several observers have recorded changes in the ganglia, and in the cardiac and other plexuses.

The degeneration of the nerve fibres has been carefully studied by Scheube, Baelz, Hamilton Wright, and Dürck. The neurokeratin network becomes irregular, and its meshes wider, while its rods disappear. The medullary sheath becomes vacuolated, and its inner boundary ill-defined. In other places the neurokeratin network condenses into small rosary-like masses or larger lumps, somewhat regularly arranged. Later the medullary sheath breaks up into spherical or elongated masses separated by clear intervals. The axone undergoes first chemical changes, and then appears like a wavy cord, or as a series of comma-like segments, or twisted up into a coil. Finally, both axone and medullary sheath disappear, while Schwann's sheath collapses, and so the nerve fibres become lost in the connective tissue of the endoneurium. Along with these changes there is a cellular infiltration of the perineurium, especially of the perivascular spaces, and also of the endoneurium. These cells are said to be like a similar infiltration met with in traumatic lesions of nerves, and to resemble the granule cells of the central nervous system. When fully degenerated, the nerve may consist simply of connective tissue. Regeneration has not been observed, but must occur—at all events, to some extent—in cases which recover.

The muscles show atrophied and normal fibres side by side. The diseased fibre first loses its striation, and becomes oval or round in transverse section. A colloid degeneration occurs, with proliferation of the nuclei of the sarcolemma. The fibre now appears of a homogeneous grey colour, and is very brittle. As it atrophies the connective tissue of the muscle increases in amount. The bone-marrow is said to be normal.

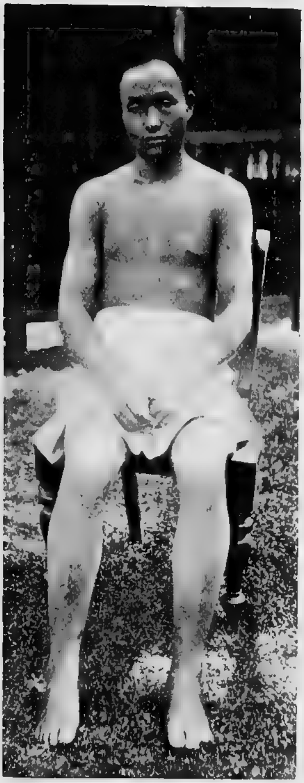

FIG. 330.—BERI-BERI: DROPSICAL OR HYPERTROPHIC FORM.

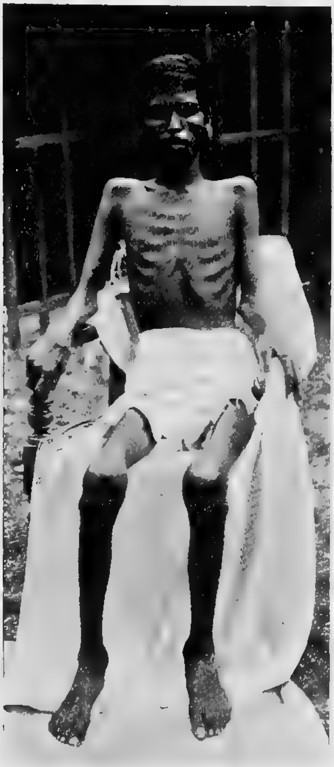

FIG. 331.—BERI-BERI: DRY OR ATROPHIC FORM.

Symptomatology.—As the cause of the disease is unknown, and the invasion is insidious, the incubation period is also unknown. Hamilton Wright places it at some ten to fifteen days.

The disease is insidious in its onset, and is characterized by gastro-intestinal, cardiac, and nervous symptoms. For purposes of description three types may be recognized—viz., (1) the acute pernicious form; (2) the typical form; (3) the rudimentary form.

1. **Acute Pernicious Form.**—The acute pernicious form may exhibit itself in several ways. The most acute is when the person, without previous illness, suddenly dies, and the autopsy reveals that he has died of beri-beri.

The more usual history is that the patient feels a disinclination for food, followed in a short time by a sensation of depression or pain in the epigastrium, and nausea. Tenderness is evinced if pressure is made over the pylorus or duodenum, while the throat is seen to be congested. The temperature is usually normal, though slight febrile rises have been recorded. Soon the heart symptoms, characteristic of the attack, appear in the form of a sensation of oppression over the heart, throbbing vessels in the neck, epigastric pulsation, cardiac palpitation, and dyspnœa, while the slightest exertion increases the pulse-rate markedly. The right side of the heart dilates, and hæmic murmurs are heard. As a result of this cardiac disturbance the urine diminishes and dropsy appears, but this varies from being trivial to fairly considerable, with effusion into the pericardium, pleura, and peritoneum.

There may early be found patches of anæsthesia or hyperæsthesia, particularly in the course of the anterior tibial and musculocutaneous nerves. Paralysis now appears, and may be slight, or may be so extensive as to prevent all voluntary movements, and at the same time the anæsthesia may increase considerably.

Sooner or later the cardiac symptoms become worse; the pericardial distress becomes agony, the lungs become engorged, and the unhappy individual, unable to obtain proper aeration of his blood, gasps for breath with open mouth and expanded nostrils, while the pupils dilate. His face becomes cyanosed, his extremities cold, and he becomes unconscious, and shortly dies of cardiac failure. During this dying agony the mind is clear almost to the last. The duration of such an attack is from twelve hours to a few days.

2. **The Typical Form.**—The typical form of the disease begins insidiously with malaise, lassitude, loss of appetite, dull pain in the stomach, tenderness on pressure over the pylorus and duodenum, headache, difficulty of breathing and palpitation, often some œdema along the shin, exaggerated knee-jerks, and a sensation of heaviness in the limbs, especially in the legs. Sooner or later a difficulty in walking sets in, and the knee-jerk diminishes and disappears, or the patient may suddenly find himself on wakening in the morning unable to raise himself. If he is capable of walking, the gait is peculiar, somewhat resembling that of locomotor ataxia, but generally being more of the ‘high-stepping’ type, the foot being raised with difficulty from the ground, brought forward with a jerk, and lowered abruptly. He walks with a support, and often with the legs wide apart, in order to give stability to his locomotion. He cannot stand long with closed eyes, and complains that he feels as though he were walking on something soft. In addition he suffers from cramp, and his calves are very tender, and

sensations of pins and needles, burning, etc., may be felt. It will be noticed that the anterior tibial and the peroneal muscles are mostly affected, and that often there is a tendency for the foot to assume the equino-varus position, and that ankle-drop is often seen.

The forearms may also be paralyzed, and wrist-drop, with great loss of power in the grip, may be noted. As the paralysis proceeds the muscles waste, and electrical excitation is much altered. Miura's rule is that if the foot can be flexed on the ankle, the excitation is only diminished; if only the toes can be dorsally flexed, there is a partial reaction of degeneration; but if no dorsal movement is capable of being made, then the reaction of degeneration will be fully developed. The paralysis spreads to the muscles of the calf, the muscles of the thigh, and the gluteal region, and to those of the hand and arm; then to the abdomen, the diaphragm, the intercostals, and the larynx, and, in rare cases, to the intra- and extra-ocular muscles.

Associated with the paralysis there is at first hyperæsthesia, especially in the calf muscles; paræsthesia, as already mentioned; and partial anæsthesia, which may be characterized by saying that the patient feels as though he were touched through some protecting cloth. There is also loss of sense of heat, and cold, and pain. This anæsthesia varies much in site and extent. Usually it begins about the feet and wrist, and moves upwards over the legs, thighs, forearms, and arms, and down into the fingers. It is this numbness of the fingers which incapacitates the patient from doing many simple actions. There is said to be a peculiar ring of anæsthesia around the mouth. The areas of loss of sensation do not correspond with segmental or nerve areas, but are remarkably patchy. The nerves of the affected regions may be tender.

The heart is also markedly affected, being dilated, especially the right side, with a diffuse apex-beat, a spacing of the sounds, so that the intervals may be nearly equal; while systolic murmurs may be heard, and reduplication of the second sound is common, particularly over the pulmonary area. Palpitation and epigastric pulsation are common, as is pulsation of the carotids and veins of the neck. The pulse is usually much increased in frequency and low in tension. The great danger of the disease is death from sudden cardiac failure.

The blood does not show much abnormality beyond a certain amount of anæmia.

The urine may be much diminished when there is œdema, but when this is passing off there is a large increase in the quantity. The total solids are said to be below normal, urea and chlorides being diminished, phosphates and indican being increased, and albuminuria being rare.

Dropsy may or may not be present, but some œdema, most marked anteriorly in the legs, is a practically constant symptom. It usually begins along the shin in the form of rather a solid œdema. It may spread over the legs into the scrotum, on to the abdominal wall, and into the face and arms, and is characterized by being at times in peculiar localized patches, and if it takes place in the muscles, gives rise to an appearance like pseudo-hypertrophic paralysis. Along with the cutaneous œdema there is often exudation into the peritoneal, pleural, and pericardial cavities.

When the dropsy is marked there may be a great diminution of the urine. This dropsical condition is often improperly considered to form a separate variety of the disease, and is called the 'wet,' 'hypertrophic,' or 'dropsical' form, while another variety, called 'dry' or 'atrophic' beri-beri, is mentioned by many authors, the two forms being merely the early and late stages of the disease.

The tongue is usually clean; the throat may be slightly congested; digestion is fair, but a large meal will increase the præcordial or epigastric distress. Vomiting is a bad sign. The bowels are often constipated, the temperature normal or subnormal. The urine may be diminished, increased, or normal in quantity, according as to the presence, the passing off, or the absence of œdema.

The larynx may be paralyzed partially or completely, and the voice rendered raucous or lost. The lungs may be œdematous.

In this condition the patient may remain, at times better, at times worse, for weeks and months, and may proceed slowly to recovery, with, of course, deformities if paralysis remains, or may die suddenly of cardiac failure when sitting up or getting out of bed, or from some complication.

3. **Rudimentary Form.**—There is a rudimentary, abortive, or ambulatory form in which the symptoms are so slight that perhaps the sufferer does not seek medical advice, but in whom there may be first increase and then diminution of the knee-jerks, patches of anæsthesia, some muscular weakness, some gastric catarrh, and general malaise.

Reinfection and Relapses.—An attack does not confer an immunity. On the contrary, it rather predisposes to another attack. It is probable that there are no relapses, but reinfections, even shortly after an attack, are common.

Complications.—Whenever fever develops in a beri-beri patient there is sure to be a complication. The most common are tuberculosis, dysentery, and malaria.

Sequela.—Many authors do not believe in sequelæ to beri-beri, but certainly there may be the contraction left after the paralysis and anæmia, and attacks of palpitation may occur.

Diagnosis.—The principal positive signs on which to base the diagnosis are: (1) Loss of knee-jerks; (2) patches of anæsthesia, and occasionally hyperæsthesia, on the legs; (3) pain on pressing the calf muscles; (4) œdema along the shin; (5) absence of marked albuminuria; and (6) the absence of fever.

Suspicious early signs in endemic areas are loss of appetite and a desire for lighter food, together with tenderness over the pylorus and duodenum, with exaggerated knee-jerks.

Several diseases have to be distinguished from beri-beri; first of all, the different kinds of peripheral neuritis—*e.g.*, alcoholic neuritis, by the history and the general tremulousness; arsenical neuritis, by the abdominal pains and the diarrhœa; lead paralysis, by the colic and the blue line on the gums.

Secondly, dropsies due to heart disease are recognized by the murmurs and the history of rheumatic fever, or other infectious disease; kidney disease, by an examination of the urine; agchylostomiasis, by the ova being found in the fæces; epidemic dropsy, by the fever and the absence of anæsthesia and paralysis; malarial cachexia, by the enlargement of the spleen, and perhaps the parasites in the blood; and kala-azar, by the enlarged spleen and liver.

Thirdly, certain diseases of the spinal cord: myelitis, by the loss of control over the bladder and rectum; locomotor ataxy, by the Argyll-Robertson pupil, etc.; pellagra, by the skin eruptions.

Fourthly, certain intoxications, such as ergotism by the gangrene and the history, and lathyrism by the absence of tender muscles.

Prognosis.—The acute pernicious form is always fatal, the rudimentary never. The general mortality varies in different countries, as follows:

	Per Cent.
Sumatra	60 to 70
Hong Kong	48·6
Malaya	19·7
Java	2 to 6
Japan	2·5 to 3·5

But it apparently depends upon many things, of which the most important is the avoidance of sudden cardiac failure. If the patient is treated carefully in bed the danger is much diminished, but if he is allowed to sit up and move about the danger is great. Complications are most unfavourable.

Treatment.—The treatment is essentially symptomatic, the patient being placed in bed, and care being taken to avoid anything which is likely to bring on cardiac failure. Especial care is required if the patient gets up or moves about. A cardiac tonic, in the form of strophanthus or digitalis, is advisable, and amyl nitrite, nitroglycerine, or trinitrin should be placed at hand, in order that they may be used at once if a sudden cardiac attack takes place. If the attack is severe, with great embarrassment of the right heart, it has been advised to perform venesection, and remove some 8 ounces of blood. Oxygen is useful during the attacks of dyspnœa.

For the paralysis strychnine should be administered, and the muscles massaged to prevent atrophy and cramps. Electrical excitation is also good.

If possible, the patient should at once be removed from the place in which he is supposed to have acquired the disease.

With regard to after-treatment, any deformity, such as club-foot, must be rectified, as described in works on orthopædic surgery. The patient must be placed upon a good nourishing diet, with plenty of proteid and good vegetables, and rice should be eliminated from this diet. Careful nursing is necessary because of the danger of cardiac failure, and good hygiene is also necessary.

Prophylaxis.—As the causation is unknown, not much can be said with profit with regard to prophylaxis, but a good nourishing diet is most important. Good hygienic surroundings—*i.e.*, good ventilation, the avoidance of overcrowding, plenty of sunshine, and exercise in the open air—may be mentioned.

It is as well to thoroughly disinfect with Clayton gas or sulphur and formalin any room in which beri-beric patients have been living, or any infected house or ship.

Rice should also be avoided as an article of diet.

EPIDEMIC DROPSY.

Synonym.—Acute Anæmic Dropsy.

Definition.—Epidemic dropsy is an acute infectious disease of unknown cause, characterized by fever, dropsy, an erythematous eruption, and sometimes cardiac symptoms, but without paralysis or anæsthesia.

History.—In 1876-77 there was a great famine in Southern India, during which a dropsical disease, at the time called 'beri-beri,' was noted. It is possible that this dropsical disease was conveyed in some way from Madras to Calcutta, for in 1877 there was an outbreak of epidemic dropsy for the first recorded time in that city. It appeared when the rains were over, and extended through the cold season into 1878, disappearing when the warm weather commenced in April. It recurred again, and followed the same course in the cold season of 1878 and 1879, and it disappeared in the warm weather of 1880, reappearing this time in the warm weather of 1881. It only attacked natives of India, but it spread from Calcutta to Shillong, Dacca, and South Sylhet, and to Mauritius, by means of labourers passing through that town. Mauritius became infected in 1878, and was clear of the disease in 1879.

No further accounts of the complaint appeared until 1901, when it was again recognized in Calcutta and Madras. In 1902 it occurred in the Barisal Gaol in Bengal, and in 1907 it occurred in Assam and the two Bengals. It is probable that during the intervening years it has really been present in some part of India, but has been called 'beri-beri.'

Climatology.—So far the disease has only been met with in India and Mauritius, and generally in the cold season.

Ætiology.—The causation of the disease is unknown, but there are various theories—*e.g.*, (1) that it is beri-beri; (2) that it is a post-dysenteric anæmia or hydræmia; (3) that it is due to nitrogen starvation ; (4) that it is due to eating Burma rice, the action of which is explained in various ways ; (5) that it is dâl poisoning ; (6) that it is a special bacterial disease conveyed from person to person by the bed-bug.

This latter is Delany's theory, and is supported by the fact that the disease is epidemic, and spreads apparently by the agency of human beings, but not from man to man ; that it begins with an initial fever, and has a rash, and that there is a local house infection ; and, finally, by its sudden disappearance and reappearance. Other theories are that it is a ptomaine poisoning, or a bacillus in fish, or a rust or fungus on rice.

Pathology.—No remarks can be made on this part of the subject.

Morbid Anatomy.—There is subcutaneous œdema and fluid in the peritoneal and pleural cavities. The mouth and pharynx are œdematous, and the œsophagus may be ulcerated. The stomach is very congested, and may show hæmorrhagic patches, and the jejunum is congested, as are the mesenteric glands and the liver. The pancreas is normal. The aryepiglottidean folds and the lungs are œdematous and congested. The kidney is congested, and may show cloudy swelling, but the bladder is normal. The spleen is shrunken ; the pericardium may be normal, but the heart is dilated.

Symptomatology.—Generally there are no distinct prodromata ; occasionally the onset of the disease is preceded by diarrhœa.

Epidemic dropsy begins with an attack of fever without any initial rigor, the temperature rising to 99° to 104° F., and continuing with remissions and, later, intermissions for a variable period of time, sometimes as long as a month. Associated with the fever, and, indeed, the most constant and characteristic symptom, is the dropsy, which, beginning in the feet and legs, may spread up the thighs on to the abdomen, and even on the hands, arms, and face.

There is distinct anæmia after the disease has lasted a little time. Rogers records a count of 3,090,000 erythrocytes per centimetre, and a hæmoglobin count of 54 to 65 per cent. The colour index is said by other observers to be about normal, and the proportion of white to red cells to vary from 1 to 430 at the invasion, to 1 to 384 in the course, to 1 to 615 at the end. Leucocytes are apparently always increased in number, but only slightly. The differential count is :

	Per Cent.
Polymorphonuclears	60·2
Lymphocytes	21·4
Mononuclears	11·7
Eosinophiles	6·7

No animal or vegetal parasites have been discovered in blood which is sterile.

The condition of the urine is described as very variable, but there is no albumin and no casts.

Effusions into the peritoneal and pleural cavities may take place. The alimentary canal is early irritated, and vomiting and diarrhœa are common occurrences. A rash appears early on the extremities in the dropsical areas ; it is usually erythematous, but vesicles and hæmorrhages may be seen. Anæmia, as remarked, is progressive during the disease, and there may be cardiac dilatation with hæmic murmurs. In severe cases there may be cough and dyspnœa, due to œdema into the lungs. Recovery is the rule, but death may occur from cardiac or pulmonary complications.

Sequelæ.—The only sequela so far observed is cardiac weakness.

Diagnosis.—Epidemic dropsy shows the following characteristic signs : dropsy, fever, diarrhœa, rash, anæmia, and no albuminuria.

Its diagnosis from beri-beri is based upon the presence of fever, the persistence of the knee-jerk, the lack of paralysis, of painful muscles, and of anæsthesia.

Prognosis.—The prognosis is favourable except in the aged, the case mortality being only 2 to 8 per cent.

Treatment.—Rest in bed and the administration of calcium chloride, or iron and strophanthus, are the only remedies usually required. High temperatures should be treated by diaphoretics, quinine, and sponging.

Prophylaxis.—Segregation and disinfection are recommended, but no rational prophylaxis can be advised as long as the cause remains unknown.

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CHAPTER XL

PELLAGRA, HISTOPLASMOSIS, AND ONYALAI

Pellagra—Histoplasmosis—Onyalai—References.

PELLAGRA.

Synonyms.—Malattia della Miseria, Mal del Sole, Malattia della Insolazione di Primavera, Risipola Lombarda, Mal de la Rosa, Mal Roxo, Mal d'Asturias, Maïdismus, Psychoneurosis Maïdica, Raphania Maisitica, Lepra Italica, Scorbutus Alpinus, Qushuf, Gofar, Lahooh.

Definition.—Pellagra is a chronic disease of unknown causation, characterized by gastro-intestinal, cutaneous, and nervous symptoms, sometimes ending in insanity.

History.—Mal de la rosa was first fully described by Casel in the Oviedo district of Asturias in 1735, though a description of the malady, not so complete, had already been given in Ramazzini's 'Diseases of the Working Class,' published in Italy in 1700. Thiéry, in 1755, wrote an account of the complaint, but he was acquainted with Casel's treatise, which was being prepared, though it was not published till 1762. About 1750 pellagra appears to have become well known in Italy, and in 1818 the first cases in France were seen by Hameau around Teste-de-Buche, in the Plain of Arcachon. In 1833 it was recognized in Roumania, in 1839 in Corfu, in 1893 in Egypt by Sandwith, though he states that Pruner had noted it in 1847.

Climatology.—Pellagra occurs in Europe, especially in Spain, Italy and Southern France, Roumania, Portugal, Austria and Turkey. In Africa it is known in Egypt, Algeria, Tunisia, and South Africa. In Asia it has been reported from Asia Minor and India. In America it occurs, and is spreading, in South Carolina and other Southern States, in Mexico, Brazil, Argentina, and the West Indies.

Ætiology.—The causation of pellagra is unknown, and therefore there are numerous theories, which include insolation, poverty, insanitary dwellings, syphilis, irritant oils, bad water, alcohol, garlic, onion, maize, leprosy, fungi, bacteria, and protozoa.

The majority of these theories can be dispensed with without remark, but two call for further consideration—viz. :

I. The Maize Theory.
II. The Protozoan Theory

I. The Maize Theory.—The maize theory alleges that the disease is a maïdismus—that is to say, a disease in some way caused by the ingestion of maize.

The supporters of this theory point out that the plant, which is a native of the Western Hemisphere, is said to have been brought to Spain by Christopher Columbus, but was not grown at all extensively till the first quarter of the sixteenth century, and they further point out that it was in Spain that the disease was first discovered.

From Spain maize appears to have been introduced into Turkey, and from thence to Italy in the middle of the sixteenth century, where it is still known as the 'grano Turco.' From the middle of the seventeenth century there was a general cultivation of maize in Italy, where the disease was recognized early in the eighteenth century in the vicinity of Sesto Calende, on Lago Maggiore. Early in the eighteenth century maize was introduced into Roumania by Niclaus Maurocordato, and the disease was first recognized in 1833. About the beginning of the nineteenth century maize appeared in France as a cultivated product, and the first cases were recognized in 1818 by Hameau around Teste-de-Buche, in the Plain of Arcachon.

In Corfu the disease was first recognized in 1839. Sandwith remarks that as long as the peasants of Corfu grew their own maize they did not suffer, but when they took to vine-growing they ate maize imported from Roumania, which had been damaged by water during transit via the Danube and Black Sea, whereupon pellagra appeared.

Such is the history of pellagra and maize side by side. From this history one would infer that pellagra is a recent disease, and that it is associated with maize. On the other hand, Sambon says that Oviedo was the least affected region in Spain in 1900, though the people cultivate, store, prepare, and eat the maize just as they did years ago, while Madrid was the most affected.

Recently in Italy, Grosseto in Tuscany, Campobasse, Teramo, Aquila in Abruzzi, and Molise, in all of which maize does not represent a principal article of food, have been affected. In fact, Sambon points out that, once established in a region, pellagra is very permanent, and that it tends slowly to spread, and that this is independent of maize cultivation.

The various theories as to the way in which the disease is caused by maize are—(1) that it is caused by normal maize ; (2) that it is caused by damaged maize.

1. Normal Maize.—The theories under this heading are that the causation is due to—(*a*) the low nutritive value of maize ; (*b*) a toxin or poison inherently present in maize ; (*c*) normal maize producing an auto-intoxication in the human body.

The first theory is based upon the idea that an exclusive, or at least a preponderant, diet of maize, by reason of its small nutritive value, and more particularly of the small amount of nitrogen it contains, causes the disease. This theory is untenable, because chronic inanition is quite a different pathological entity from pellagra, and many people live on rice and potato, which have lower nitrogen ratios than maize. The second theory states that not merely is there a poison in maize, but also that there is an individual susceptibility in men. The third theory asserts that poisons are generated in the bowel from the grain (Neusser) by the aid of the *Bacillus coli communis* (De Giaxa). This latter theory of De Giaxa is supported by experiments, for he produced the symptoms in animals inoculated by the toxin produced by growing the *B. coli communis* in maize media.

2. Damaged Maize.—At the present time the popular belief is that the disease is caused by maize damaged by being cultivated and harvested under

unfavourable circumstances, and stored in such a damp condition that it becomes mouldy. This has been supported by Hirsch, who points out that a bad maize harvest is followed by an increase in the cases of the disease. The theories as to the substance in the damaged maize which causes the disease are manifold, and may be classed into (*a*) Fungi, (*b*) Bacteria, (*c*) Chemical substances.

(*a*) *Fungi.*—Monti and Tirelli showed that fungi were commonly found in maize, those most usually met with being *Penicillium glaucum, Rhyzopus nigricans, Mucor racemosus*, and species of *Aspergillus* and *Saccharomyces*. The special fungus, *Sporisorium maïdis*, described by Ballardini in 1845 as the cause of the disease, is probably only *P. glaucum* or *M. racemosus*, the former being held by some writers to be the causative agent, but its effects on men and animals are quite different from pellagra. *Aspergillus fumigatus* and *A. flavescens* (or *A. varians*) have been obtained by Ceni in pure cultures from the lungs, pleura, and pericardium of pellagra cadavers, but the symptoms of the disease are quite different from aspergillosis. Later, Ceni and Fossati have stated that the real cause of the disease is the toxin from the fungi.

(*b*) *Bacteria.*—Monti and Tirelli showed that many bacilli grow in maize—*e.g.*, *Bacillus solanacearium*, and another like *B. subtilis*—and it has been shown, by Paltauf that the so-called *B. maïdis* of Majocchi and Cuboni is only the common potato bacillus. Another bacillus, called *B. pellagræ*, is stated by Carrarioli to produce toxins, which, when injected into animals, produce the typical symptoms of the disease.

Tizzoni has described a bacillus found in the cerebro-spinal fluid of pellagra patients.

(*c*) *Chemical Substances.*—Numerous observers have reported poisons in fermenting maize. Thus, Lombroso in 1871 obtained two alkaloids, one like conium and the other like strychnine, but the symptoms produced by these on men and animals were not like those of pellagra. Others have reported tetanic or narcotic poisons, etc.; but, on the other hand, Monselice failed to obtain any such poisons in damaged grain from pellagrous districts.

The maize theory is therefore by no means proved, and, in fact, is at present very doubtful.

II. The Protozoan Theory.—Recently Sambon has suggested that the disease may be due to a parasitic protozoon. He bases his theory on the facts that, once introduced into a country, the disease tends to spread; that the morbid anatomy resembles to some extent that of trypanosomiasis; and that there is a mononuclear leucocytosis. We may add that the beneficial effect of arsenic and atoxyl is also in favour of this theory.

With regard to predisposing causes, it is noted that it is generally the labourer in the field who is attacked, while the resident of the town escapes. It is said to be more prevalent among men than women, and to occur generally between the ages of twenty and fifty years. The seasonal incidence is most marked, first attacks and recurrences taking place in the spring.

Pathology.—As the causation is unknown, the pathology is purely speculative, but it appears as though some agent, chemical or living, were attacking the cerebro-spinal nervous system, and also rendering the skin more liable to irritation by the sun's rays; for the essential pathological features in the nervous system, according to Mott, are the perivascular infiltration and the leptomeningitis, reminding the reader of trypanosomiasis; and this, together with the mononuclear leucocytosis, makes the theory of Sambon—that the disease will eventually prove a protozoal infection—worthy of the most serious consideration.

With regard to the skin eruption, attention may with advantage be drawn to Wedding's experiments on light and parti-coloured beasts, which, when fed on buckwheat in the dark, remained healthy, but when exposed to the sunlight, broke out in blisters on the light-coloured portions, thus showing that a chemical substance taken internally may evoke an inflammation in parts exposed to the sun. The blood shows a diminution in erythrocytes and hæmoglobin, and an increase in mononuclear leucocytes. The urine may be normal, or may, towards the end, be alkaline; the specific gravity may be as low as 1005, and albumin is rarely present. The Wasserman reaction is said to be positive.

Morbid Anatomy.—The body is greatly emaciated and markedly anæmic; the skin is rough and atrophied, and the subcutaneous fat is diminished. Microscopically the skin shows stenosis of the blood-vessels of the papillæ and corium, and atrophy of the horny layer. The muscles, heart, liver, spleen, and kidneys are all atrophied, while the lungs at times show tuberculosis.

The stomach is usually normal, but the intestines are atrophied, especially as regards the muscular coat, which is hyperæmic. The rectum also may be ulcerated. The nervous system shows a chronic diffuse leptomeningitis, with marked thickening in places. There is perivascular, round-celled infiltration, with pigmentation and degeneration of the nerve elements. In the brain the convolutions, especially the frontal, are atrophied, and the ventricles contain an excess of fluid. Rarely a calcareous deposit is found in the blood-vessels. In the spinal cord there is often sclerosis of the postero-lateral and postero-median columns, and in the dorsal region lateral sclerosis. The posterior roots are sometimes involved.

Symptomatology.—The incubation period is quite unknown, and the onset is insidious, being marked by prodromata in the form of gastric disturbance, as evinced by a failing appetite, a coated tongue, and dyspepsia, together with signs of a general infection or intoxication, which is characterized by anæmia, pains in different parts of the body, and a peculiar morose, irritable, mental condition.

The disease begins with gastro-intestinal disturbance, the coated tongue of the prodromal stage being changed by a stripping off of the epithelium into an abnormally clean tongue. A similar condition of rawness may extend to the palate and œsophagus. Associated with this there may be a bleeding and spongy condition of the gums, which gives rise to the synonym 'Alpine scurvy,' which only appears, however, if there is a lack of fresh vegetables. The teeth are not affected in ordinary cases of pellagra, but the salivary glands may undergo a painless enlargement, especially the parotid, and more rarely the submaxillary and sublingual glands. This enlargement is bilateral, and never ends in suppuration. As a result of these conditions the mouth is sore, and is often dry, but notwithstanding all this the patient has an abnormally good appetite. There are the usual signs of chronic gastritis with fermentation—viz., flatulency, pain, tenderness, and thirst—but as a rule no vomiting. Diarrhœa is the most common symptom of the irritated condition of the bowels, and blood-stained motions may be passed, but constipation may be present in the earlier stages. There is usually some pain and tenderness in the lower part of the abdomen.

Associated with the digestive disorders there is a cutaneous erythema, produced by the sun's rays at the time at which most actinic (ultra-violet) rays are present—viz., in the spring, in Italy and Egypt. This eruption is limited to the regions exposed, being at first delineated in a most exact manner by the clothing. It appears on the dorsum of the forearms, and on the hands and feet, only reaching the flexor aspect after several attacks. The most common sites are the hands and forearms, elbows, feet, legs and knees, the upper part of the chest, the shoulders, neck, and face. Sandwith points out that in Egyptian peasants the unguinal phalanx of the hand is seldom affected, due to the fact that when the hoe is grasped it is protected against the sun's rays. The nails and hair are not affected.

The skin eruption may show the following conditions: (1) congestion; (2) inflammation; (3) thickening and pigmentation; (4) atrophic thinning.

The affected part turns a bright, dark, or livid red colour, which at first disappears on pressure. Associated with this erythema there is a burning sensation, but usually no pain. In course of time the part becomes swollen and tense, and bullæ may form. After lasting a variable period of days or weeks, the eruption gradually subsides, leaving the skin rough, pigmented, and thickened, and thus earning the names of 'pell'agra' and 'qushuf.'

This erythema disappears in the winter, but reappears the next spring with increased virulence, and in due course develops into a dermatitis, which produces an exfoliation of the epidermis in grey or brown flakes. Every attack leaves the affected area a little more pigmented, a little more thickened, and a little less elastic.

After lasting about four or five years the skin begins to atrophy, and becomes wrinkled and inelastic. This atrophy is most marked at the sides of the neck, on the back, hands, and feet. Pain is often complained of in the back, and, according to Sandwith, tenderness is found on pressure over the spinal nerves on either side of the dorsal or lumbar portions of the vertebral column. Muscular weakness is noted, especially in the legs. The knee-jerk is at first exaggerated, but later is diminished, and finally lost. Ankle-clonus and wrist-clonus are rare, and only occur when the knee-jerk is exaggerated, when there is tenderness on both sides of the dorsal and lumbar cord, and when abdominal and epigastric reflexes are also increased.

There is no special gait, but there is a tendency to fall backwards or forwards, and hence, though the patient walks with the legs well apart, he can only take a few steps without falling down. There may be tremors in the legs and tongue. The bladder and rectum are not affected until the end, and contraction of the limbs does not take place till bedridden. Trophic lesions, such as bedsores, are of rare occurrence. Hyperæsthesia may occur in different parts of the body, and pains (even of a lightning nature) may exist in the head and back, and be associated with cramps.

The facies of the pellagra patient is one of anxiety and mental worry. He cannot sleep, and there is often great mental depression and discontent, but some are excitable and irritable, while others are stupid and morose. For a year or two the mental condition remains normal, but gradually the patient becomes sad and stupid, melancholic and sleepless. He loses his memory, and has vague feelings of pressure, weight, or pulsation about his head. From this he proceeds to refusal of food and suicidal tendencies, with delusions of sorcery and persecution, and has a tendency to suicide by drowning. Melancholia may now become confirmed, and may eventually pass into dementia.

Various paralyses develop, such as spastic paralysis, ptosis, hemianopsia, diplopia, amblyopia, and mydriasis. The extremities and bladder now become paralyzed, and the demented, paralyzed, rapidly emaciating patient, suffering from bad sweats, profuse diarrhœa, and sometimes dropsy, obtains a relief from his sufferings in death, the disease having usually lasted from ten to fifteen years. Rarely the course is rapid, instead of being chronic.

Complications.—The disease is often complicated by the presence of agchylostomiasis, and in Africa bilharziosis and other diseases.

Diagnosis.—There is no difficulty in diagnosis if the skin eruption and later the nervous symptoms are well marked. Sprue, it is true, causes the sore mouth, but its peculiar whitish diarrhœa and the absence of the skin eruption and the nervous phenomena ought to prevent mistakes. It is hardly possible that leprosy should lead to difficulty, because the pellagra eruption does not present anæsthesia. Alcoholic pseudo-pellagra can be diagnosed by the history.

Prognosis.—Usually this is bad, but in slight cases it is more favourable if suitable treatment, good food, and hygienic surroundings are provided.

Treatment.—The best treatment is arsenic in some form, especially atoxyl (8 grains once a week), though the result is only partially successful ; otherwise it is possible only to relieve symptoms.

The diet should be good and nourishing, but maize should be avoided.

Prophylaxis.—It is obvious that the consumption of diseased or damaged maize must be injurious, and the Italian laws preventing the supply of damaged maize are commendable. As, however, there is so little definitely known with regard to the ætiology, it is impossible to give any definite rules for prophylaxis.

HISTOPLASMOSIS.

Definition.—Histoplasmosis is an acute specific infection caused by *Histoplasma capsulatum* Darling.

History.—This disease has recently been described by Darling, but being first discovered post-mortem, the clinical signs are rather deficient. The first case was in a negro who, three months previously, had come from Martinique to the Canal zone of Panama.

Ætiology.—The disease is caused by the parasite *Histoplasma capsulatum* Darling, already described in the chapters on Protozoa.

Pathology.—The parasite infects epithelial and endothelial cells of the lungs, liver, and spleen. It also exists free in these organs. In the lungs it gives rise to pseudo-tubercles resembling miliary tubercles.

Morbid Anatomy.—In the first case there were ecchymoses and small nodules beneath the visceral pleura of both lungs, which were studded throughout with pale grey hyaline and miliary tubercles, 2 to 3 millimetres in diameter, while the remainder of the organs was of a bright red colour. The peribronchial glands were full of soft caseated tubercles. The heart was small, but normal. The liver was enlarged, pale, and in a condition of slight atrophic cirrhosis. The spleen was enlarged to about three times its usual size, very firm, with distinct Malpighian bodies. The kidneys were slightly cirrhotic ; the pancreas, bladder, bone-marrow, and brain were normal, and no tubercle bacilli could be found.

Microscopically the lung tubercles were found to consist of alveoli, the walls of which were broken and collapsed, and were filled with alveolar epithelial cells distended with parasites. In the liver the hepatic cells and the vascular endothelial cells were much infected with parasites. Some areas which stained badly were found to consist simply of the débris of cells with numerous parasites. The spleen showed intracellular and free parasites.

Symptomatology.—The symptoms closely resemble those of Indian kala-azar, there being irregular fever with enlargement of the spleen and liver, and severe anæmia with marked leucopenia.

Treatment.—Nothing is known as to the treatment or prophylaxis.

ONYALAI.

Definition.—An acute infectious disease of unknown causation, characterized by the appearance of bullæ containing blood on the surface of the body, the tongue, soft palate, or buccal mucous membrane.

History.—The disease was first described by Wellman, in 1904, in Portuguese West Africa, and then by Massey, in 1904, in Angola; by Feldman, in 1905, in East Africa, where it is called ‘ edjuo ’ by the natives of Bukoba. Mense (1906) thinks that the ‘kafindo’ disease of the Unyamwezi people of the Congo is the same disease. Hæmorrhagic bullæ in the mouth, but without general symptoms, have been described by Maxwell in Changpo, South China, as being due to the accidental introduction into the mouth of a kind of spider’s web.

Ætiology.—This is unknown, but Wellman considers that it is not a manifestation of malaria; nor is it a vegetal poisoning, nor a snake-poisoning, though the bite of *Bitis arietans*, the puff-adder, simulates some cases closely. Neither trypanosomes nor bacteria can be found. It is not a purpura hæmorrhagica, nor Henoch's purpura, nor Schönlein's disease. Mense thinks it may be some kind of poisoning, perhaps with some species of the Euphorbiaceæ.

Symptoms.—The onset is sudden, and is accompanied by lassitude and a dazed appearance. Sometimes the parotids are tender, and the eyes may be somewhat reddened, and in about 66 per cent. of cases there is a slight rise of temperature. Numbness and pain in various parts of the body may be noted.

The appetite is poor; bullæ may be seen on the tongue and in the mouth and pharynx, while they also occur in the œsophagus, stomach, and bowels. The tongue is swollen and painful. Vomiting of blood is not rare, and bloody diarrhœa may take place. Hæmaturia has been noted, and cerebral hæmorrhage, with the usual signs, has been seen. It is believed that hæmorrhage into the pancreas, liver, and spleen, may take place in some cases. Bullæ may also appear in the skin, ranging from the size of a split pea to several inches in diameter. The typical bullæ, whether on a mucosa or in the skin, extend deeply, involving the submucosa or the corium, and are crossed by fibrous trabeculæ, in the meshes of which lies partially coagulated blood, which appears dark through the skin or mucosa. The red corpuscles are not disintegrated, and can be seen by the microscope.

The disease is said to have a tendency to recur two or three times.

Diagnosis.—The diagnosis from snake-bite may be effected only by the history, as the bullæ may not be visible on the skin or mucosa. Malaria can be excluded by the blood examination. Schönlein's disease, or peliosis, is diagnosed by the rash, painful swelling of the joints, and the purpuric eruption. Henoch's purpura is met with generally in children, and has joint symptoms, as well as a rash.

Prognosis.—Wellman reports three deaths in fourteen cases, and says that the malignancy varies in different seasons and districts.

Treatment.—Wellman thinks that arsenic in full doses is the best treatment. He says the natives use empirically *Geigera wellmani* Hutch and *Albizzia anthelmintica* A. Broga. Massey recommends large doses of bicarbonate of soda and cod-liver oil.

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SECTION C

SYSTEMATIC DISEASES

CHAPTER XLI

DISEASES OF THE RESPIRATORY ORGANS

General — Rhinitis spastica vasomotoria — Rhinopharyngitis mutilans — Rhinosporidiosis—Hirudiniasis—Rhinal chilopodiasis—Linguatula rhinaria—Rhinal myiasis—Bronchial spirochætosis—Tropical bronchomycosis.—References.

DISEASES of the respiratory organs are of common occurrence in the tropics, in the form of acute or chronic inflammation of the nose, throat, larynx, bronchi, or lungs. Pneumonia is less common than in Europe, and must be carefully diagnosed from pneumonic plague, liver abscess, and malaria, by careful physical examination as well as by microscopical examination of the sputum and blood. Liver abscess may burst into the lung or pleural cavity, and may cause the expectoration of a peculiarly brown and viscid sputum. Emphysema and asthma are fairly common.

Phthisis is common, and appears to be increasing in the East, but it must be remembered that the pulmonary lesions of paragonimiasis and histoplasmosis closely simulate this disease, and in certain regions the examination of the sputum is imperative. The occurrence of porocephalus in the lungs must also be remembered, and the intense congestion in heat-stroke. There are several conditions which deserve special mention with regard to tropical disease.

RHINITIS SPASTICA VASOMOTORIA.

Synonyms.—Rhinitis Nervosa, Coryza Spasmodica, Dispnée Tropicale.

Definition.—A rhinitis characterized by fits of sneezing, with the production of much nasal mucus, and obstruction of the nose from swelling of the mucous membrane over the turbinated bones. The affection has the greatest resemblance to hay fever.

History.—This disease appears to have been first described by Zegers in 1901, in Batavia, while Brero gives a full description in Mense's 'Tropenkrankheiten,' and we have seen several cases in Ceylon. O'Zoux has recorded numerous cases in the island of Réunion.

Symptomatology.—The affection is characterized by attacking adults, in whom it causes violent fits of sneezing, lasting from a few minutes to two hours, during which time the victim sneezes ten to seventy times, while fluid pours from the nose, tears roll down from the eyes, the conjunctivæ are injected, the eyelids swollen, the head aches, and the patient is unable to do his work. The attacks are repeated constantly. The attacks may be repeated several times during the day, or may not recur for weeks. They may be associated with or followed by dyspnœic conditions resembling to some extent asthma. At the beginning the mucosa of the inferior turbinated bone may appear hyperæmic, but later it becomes swollen, and has a macerated appearance. The disease therefore closely resembles hay fever, but is supposed to be caused by dust acting upon the nasal mucosa of persons, the resistance of whose nervous system has been lowered by long residence in the tropics. We have frequently met with the disease in people exposed to the dust of tea and copra.

Treatment.—The only successful treatment in many cases is a change of climate, when the symptoms stop at once. When the patient cannot have a change of climate, atropine and strychnine pills, or small doses of quinine, may be recommended, and locally a spray of a solution of cocaine (1 per cent.) and adrenalin.

RHINOPHARYNGITIS MUTILANS.

Synonym.—Gangosa.

Definition.—Rhinopharyngitis mutilans is an ulceration of the palate or pharynx of unknown cause, which slowly spreads to the nose and larynx, destroying cartilage and bone, and causing much deformity.

History.—The disease appears to have been first described in 1828 by a Spanish Commission to the Marianne or Ladrone Islands under the name 'gangosa,' which means 'nasal voice.' In 1906 the disease in the endemic area was studied by Fordyce and Arnold, by Leys in Guam, an island to the south of the Ladrone Islands, and by Mink and McLean in the Ladrone and Caroline Islands. In 1907 a paper appeared by Musgrave and Marshall on a case from the Batanes Islands, 120 miles north of Luzon, and by Stitt on a case in a European in Guam.

Climatology.—There appears to be an endemic area for the disease, it being common in the Batanes Islands (where the cases are mistaken for leprosy), in the Ladrone Islands, Guam, and the Caroline Islands. It is also said to exist in Fiji, Panama, British Guiana, Ceylon, Nevis, Dominica, and Italy.

Ætiology.—Daniels and several other authors believe it to be a sequel to yaws, but Rat is opposed to this, as are Mink, McLean, Musgrave, and Marshall. Alvarez suggested that it was syphilis, but Musgrave, Marshall, and Leys are opposed to this, because no syphilis exists in Guam, where gangosa is common. There are no signs or symptoms of syphilis in this disease; treponemata cannot be found, and mercury and iodide of potash are without effect. It is not leprosy, because of the absence of nodules, infiltration, anæsthesia, and Hansen's bacillus. It is distinguished from epithelioma by the absence of the histological characters and metastases, as well as by the protracted course. It is excluded from tuberculosis by the absence of Koch's bacillus and other symptoms of the disease, and the failure to inoculate guinea-pigs successfully. It is therefore probably a separate disease of unknown causation.

Pathology.—It appears to begin sometimes as a sore throat or coryza, or as a tubercle on the palate. In any case an ulcer soon forms, which, though superficial at first, eats through cartilage and bone, with periods of quiescence and of activity. This ulceration is due to a necrosis of the tissue elements, with very little reaction on the part of the body. This reaction is apparently limited to a small-celled infiltration, some giant-celled formation, and proliferation of bloodvessels with the formation of granulation tissue.

Morbid Anatomy.—The post-mortem may reveal signs of some concomitant affection—for example, tuberculosis, pleurisy, or cardiac hypertrophy—which have nothing to do with the disease, the important features of which are ulceration and destruction, together with scar formation in the larynx, pharynx, palate, nose, and perhaps the antrum of Highmore.

Microscopically, the following changes are observed as the diseased area is approached from healthy tissue. First there is an œdematous infiltration, then an infiltration with round cells, which are principally lymphocytes, associated with another variety possessing more protoplasm, and a small dark nucleus. Sometimes there are giant cells and proliferating vessels, and there are always hæmorrhages. Then comes a layer of necrosis, forming the surface of the ulcer, at the edges of which the epithelium can be seen, sending processes into the subcutaneous tissue, which consist of large vacuolated cells with pale vesicular nuclei. Some diplococci, micrococci, and bacilli have been noted, but no acid-fast bacilli or treponemata have been seen.

Symptomatology.—The disease begins as a sore throat, and on examination a nodule may be seen on the back of the pharynx, the posterior pillars of the fauces, or the edge of the soft palate. This becomes a superficial ulcer covered with a brownish-grey slough. This ulcer spreads rapidly at first, but more slowly later, and eats away first the soft parts, and then the bone of the palate, the nasal septum, and the cartilages of the nose, so that the skin falls in, and the nose and mouth are converted into one cavity. It may then extend on to the face or lip, or affect the larynx. Sensation is diminished over the ulcer, and a most objectionable odour is exhaled, while a slight discharge of granular and necrotic débris is generally present. The ulceration may progress continuously for a period of ten to thirty-five years, or it may advance at certain times and be quiescent at others, or it may cease at any time, leaving a chronic ulcer.

With regard to the blood, Musgrave and Marshall report that their case showed no marked leucocytosis and no abnormal elements. The hæmoglobin was 80 per cent., the leucocytes 11,600 per cubic millimetre, the small lymphocytes 10 per cent., large lymphocytes 4·6 per cent., polymorphonuclears 82 per cent., eosinophiles 2·6 per cent., basophiles 0·4 per cent.

The disease is limited to the throat and nose, and as a rule the general health is but little affected.

A fulminating variety has been described by Mink and McLean in children which is fatal in forty-eight hours, and closely resembles diphtheria, without, however, the presence of the specific bacilli.

Diagnosis.—The diagnosis has been practically discussed in the Ætiology, and need not be repeated, except to say that it must be made by a process of exclusion.

Prognosis.—The disease is rarely fatal.

Treatment.—Nothing is at present known which is capable of arresting its progress. An application of a strong solution (1 per cent.) of permanganate of potash is recommended as a deodorant, and local application of tincture of iodine or the actual cautery.

Prophylaxis.—Nothing can be said under this heading, as the ætiology is quite unknown.

RHINOSPORIDIOSIS.

Definition.—Rhinosporidiosis is an infection of the nasal mucosa, with *Rhinosporidium kinealyi* Minchin and Fantham, which produces polypoid growths.

History.—In 1903 Kinealy reported to the Laryngological Society a peculiar case of a polypus growing from the septum of the nose of an Indian in Calcutta in the form of a pedunculated, raspberry-like body, with whitish spots on the general red surface. On section this tumour was found to have peculiar bodies embedded in it. It was then carefully examined and described by Minchin and Fantham, who came to the conclusion that the peculiar bodies were haplosporidians, and named them *R. kinealyi.* In 1905, Nair of Madras found similar nasal polypi in several people, who all came from the small native State of Cochin, on the west coast of India. These polypi were carefully described by Beattie in 1906.

Climatology.—At present it is only known in India.

Ætiology and Pathology.—The cause of the disease is *R. kinealyi* Minchin and Fantham, which by its growth causes the formation of a polypus, as has already been described in the chapter on Protozoa (p. 333).

Symptomatology.—The patient has his attention drawn to his nose by profuse bleedings, and in a little time notices a growth. On examination this is found to be a small vascular pedunculated tumour, about the size and shape of a pea, freely movable and painless, attached to the anterior and upper part of the cartilaginous septum. In appearance it resembles a strawberry or a raspberry.

Prognosis.—It does not appear to be dangerous to life.

Treatment.—The treatment is removal and cauterization.

HIRUDINIASIS.

Definition.—Hirudiniasis is the invasion of the nose, mouth, pharynx, or larynx by leeches.

Climatology. — Leeches have already been described in Chapter XVII., when it was mentioned that they were apt to invade the nose, mouth, pharynx, or larynx. Recently Masterman has given a very excellent account of hirudiniasis as seen in Palestine.

Leeches are most troublesome in Algeria, Palestine, and Ceylon, less so in the Philippine Islands, Java, Sumatra, Australia, and Japan.

Ætiology.—It is the water-leech, which lives in springs, which is the cause of trouble to man, as it is apt to be swallowed with drinking-water. This is particularly liable to take place when the traveller drinks the water hastily at dusk.

Pathology.—The leech, when in the mouth, nose, pharynx, or larynx, does not suck blood until gorged, and then detach itself from the affected part, as is the rule when it attacks the skin, but apparently bites and sucks a little in one place, and then passes to another, and bites and sucks again, and so on. Of course the sites of the bites bleed, and hence the patient may in course of time become very anæmic, and even die. It is hardly likely that a leech could live in the stomach if swallowed, though such an occurrence has been described.

Symptomatology.—The patient usually knows that he has swallowed a leech, and has felt the animal catch hold of the mucosa of the pharynx during the swallowing of the water. But children, and even adults, may be quite unaware of the accident having happened. The most important sign is the bleeding from the nose or mouth, or the hawking up of blood from the pharnyx, or hæmoptysis from the larynx, accompanied by a short irritating cough, dyspnœa, and sometimes cyanosis from the impediment to the respiration. Rhinoscopic or laryngoscopic examination may be necessary in order to see the parasite, and will require to be done with cocaine. In the larynx the head of the leech is usually fixed just inside or outside of the vocal cords, and the body may flop backwards and forwards with respiration.

Diagnosis.—The bleeding and the examination with a nasal speculum or a laryngoscope make the diagnosis easy.

Prognosis.—This is usually good if the parasite is removed in time, but if left for long, removal may be too late, and the patient succumb.

Treatment.—Apply a pledget of cotton-wool soaked in 30 per cent. solution of cocaine to the parasite. This produces a paralyzing effect on the animal, and it can then be removed. As, however, the drug requires some time to act, and the leech might fall from the larynx into the trachea, it is advisable in these cases to make the patient lie prone on a couch, with the head hanging over, when the paralyzed parasite will be coughed up.

Prophylaxis.—Filtration of the water will prevent the parasite entering the body. Masterman says that a kind of carp, Capoëta fratercula, will keep the water free from leeches.

RHINAL CHILOPODIASIS.

Definition.—Rhinal chilopodiasis is the invasion of the nose by a species of the *Chilopoda.*

Ætiology and Symptomatology.—The *Chilopoda* have already been described in Chapter XVII., and it has been pointed out that *Geophilus carpophagus* Leach, *G. similis* Leach, *G. electricus* Leach, *G. cephalicus* Wood, *Lithobius forficatus* Leach, and *L. melanops* have been found in the nasal cavities, causing inflammation, with at times a great flow of mucus, while at others there is a stoppage of the discharge. Associated with this flow there is headache, with more or less marked remissions at times, and also general symptoms, such as convulsions, angina, dyspnœa, etc., which are thought to be produced reflexly by stimulation of the fifth nerve. The symptoms are thought to be produced mechanically, and not to be due to any action of venom secreted by the parasite. Diagnosis is to be made by examination of the nose by a speculum.

Treatment.—The affection is not serious, and often the parasite is expelled by merely sneezing. More rarely chloroform-water injections, snuff, eau de Cologne, or turpentine injections, are needed. Still more rarely will a sinus, such as the frontal sinus, require to be opened.

LINGUATULA RHINARIA.

This parasite has been found occasionally in the nose of man in Europe.

RHINAL MYIASIS.

Definition.—Rhinal myiasis is the invasion of the nasal cavities by the larvæ of *Chrysomyia macellaria* and other flies.

Climatology.—The disease is met with in tropical and subtropical America, both north and south.

Ætiology.—The fly lays its eggs in the nose of a person sleeping in the open air, and the larvæ which hatch from the eggs cause the disease.

The life-history of this fly has already been fully described in Chapter XX.

Pathology.—The larvæ consume the mucous membrane, cartilages, and bones of the nose for nutriment, and may reach the nasal sinuses, the frontal sinus, the antrum of Highmore, or even the meninges at the base of the skull.

Symptomatology.—Pain associated with a discharge of blood from the nose in the endemic region should lead to the disease being suspected, and should cause a thorough examination of the nose to be made for larvæ.

Diagnosis.—This will depend upon the locality, and upon finding a larva.

Prognosis.—The prognosis is bad, unless the case is promptly treated.

Treatment.—The nose must be washed out with chloroform-water, and, if necessary, the frontal or other sinuses must be opened and irrigated. Calomel may be insufflated.

Prophylaxis.—The prophylaxis consists in the avoidance of sleeping in the open air without a mosquito curtain.

BRONCHIAL SPIROCHÆTOSIS.

Definition.—Bronchial spirochætosis is a peculiar form of bronchitis characterized by the presence of enormous numbers of spirochætes in the expectoration.

History.—Bronchial spirochætosis was first described by Castellani in 1906. In 1909 Waters described numerous cases of the disease occurring in India, while Branch in the West Indies, and Jackson in the Philippine Islands have also observed cases.

Climatology.—The geography of the disease is not fully known, but its distribution appears to be extensive, as it is known in India, Ceylon, the Philippine Islands, and the West Indies.

Ætiology.—Enormous numbers of spirochætes are found in the expectoration, and these may be classified into various groups, when coloured by Leishman's or Giemsa's stain. These groups are:

1. Very thick individuals, from 15 to 39 μ in length, with irregular coils, which vary in number, but are never numerous. These forms generally take a bluish tint with the stain.
2. Individuals resembling *S. refringens* Schaudinn, and possessing a few graceful waves and pointed extremities.
3. Thin, delicate spirochætes, with numerous small uniform coils and tapering ends. Sometimes one of the extremities is blunt, while the other is pointed. This is perhaps the commonest type.
4. Extremely thin delicate organisms, with very few irregularly shaped coils.

There is little doubt, therefore, that the term *S. bronchialis* Castellani 1907 covers several varieties of spirochætes and possibly different species.

Symptomatology.—The disease presents two types—viz., acute broncho-spirochætosis and chronic broncho-spirochætosis.

Acute Broncho-Spirochætosis.—In the acute type the patient has fever, feels weak, and suffers considerably from a cough, the expectoration being scanty and of a mucus character, but very often the general condition, according to our experience, is not bad.

Chronic Broncho-Spirochætosis.—Chronic bronchial spirochætosis may follow on an acute attack, but very frequently at least in Ceylon, the onset is quite insidious and slow. The patient has a chronic cough, which is frequently more severe in the mornings. The expectoration is not very abundant, and is muco-purulent in character.

In some cases for periods of two or three days, and even much longer, the expectoration contains blood, which is intimately mixed with the muco-pus, and varies in amount. Sometimes attacks of genuine hæmoptysis occur, one or two teaspoonfuls or more of blood being expectorated. In some cases there is no fever; in others a true hectic-like fever may be present. In some cases, however, the rise of temperature takes place in the morning, and not in the afternoon; in others the fever is present only occasionally, and is very irregular. The physical examination of the chest reveals very little except a few dry or coarse moist râles. The general condition may remain fairly good for a long time, though a certain degree of anæmia is always present. A few cases waste rapidly.

The course of the disease is very prolonged, the first case observed by Castellani in 1904 being not merely still alive in 1909, but very much improved.

Prognosis.—The prognosis is favourable *quo ad vitam*, but the disease may take a chronic course with anæmia and wasting.

Diagnosis.—The acute type is generally mistaken for influenza or malaria. The examination of the sputum in which no Pfeiffer's bacilli are found will distinguish the affection from influenza, and the examination of the blood will exclude malaria.

Cases of the chronic type presenting blood in the expectoration are generally diagnosed as phthisis. The examination of the sputum for tubercular bacilli will be always negative, and the animal inoculations will remain without effect. The ophthalmo- and cuti-reactions are negative in the great majority of cases.

Occasionally, however, cases of mixed infections of tuberculosis and spirochætosis occur, one such case being described by Branch.

Spirochætosis is easily distinguished from endemic hæmoptysis by the examination of the sputum, which will show absence of the ova of *Paragonimus westermani*.

Treatment.—Treatment with the ordinary expectorant mixture is unsatisfactory, but in chronic cases the glycerophates and arsenic give somewhat better results.

Castellani has recently called attention to the frequency in the tropics of cases of chronic bronchitis due to Hyphomycetes. The most severe type of the disease closely resembles phthisis.

The so-called 'tea-factory-cough,' commonly met with in planters and coolies in Ceylon, is often a form of bronchomycosis.

The fungi most commonly observed are: Endomyces, Saccharomyces, and occasionally Aspergilli.

The milder type is amenable to treatment by potassium iodide.

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CHAPTER XLII

DISEASES OF THE ALIMENTARY CANAL

General remarks—List of animal parasites—Diseases caused by animal parasites—Strongyloidosis—Trichuriasis— Agchylostomiasis—Ascariasis—Oxyuriasis—Gordiacea and Acanthocephala—Diplopodiasis and Chilopodiasis—Myiasis—Scoleciasis—The vomiting sickness of Jamaica—References.

GENERAL REMARKS.

THE diseases of the alimentary canal include a very large number of affections which are common to all parts of the world, and need not concern us here except to remark in passing on a few points. Cancer of the lips, cheeks, and tongue are frequently met with in Ceylon and other parts of the tropics. All forms of dyspepsia are common, but Marchoux and Brochet have specially called attention to the frequency of hyperchlorhydria and fermentation, which agrees with our own experience.

External hernia is common, but internal hernia is rare ; we have only met with one example, and then of a most unusual form, the displacement being through a rupture in the transverse mesocolon, forming a hernia into the lesser sac. This hernia probably took place through the recessus inter-mesocolicus transversa (Bröscke). Intussusception and volvulus are known, as well as intestinal obstruction due to bands, and we have met with one unique case of fatal intestinal obstruction in a native found dead, caused by the compression of the rectum against the pelvic wall by an enormously distended bladder, which we had not thought to be possible.

Cancer of the stomach and bowels is by no means uncommon, but gastric ulcer is rare, and we have only met with one case. Tuberculosis of the bowel is generaly secondary to tuberculosis in some other regions, but we have seen primary tuberculosis. Appendicitis is quite common in both Europeans and natives, and is caused by bacteria acting either directly, or introduced by the action of *Trichuris* and *Ascaris.*

We would also call attention to the frequency of intestinal sand. The true intestinal sand of animal origin composed of dark grey or colourless gritty particles, and largely composed of lime salts, is occasionally met with, but by far more common is the so-called pseudo-intestinal sand composed of undigested remains of vegetable food (bananas, etc.), which may become encrusted with earthy salts. In these cases there may be diarrhœa and colicky pains.

LIST OF ANIMAL PARASITES.

The animal parasites of the alimentary canal are :

(*a*) **Protozoa.**

BUCCAL PARASITES.

1. Entamœba gingivalis Gros.
2. ,, dentalis Grassi.
3. ,, buccalis Prowazek.

INTESTINAL PARASITES.

4. Entamœba coli Lösch.
5. ,, histolytica Schaudinn.
6. ,, undulans Castellani.
7. ,, tropicalis Lesage.
8. ,, tetragena Viereck.

*9. ,, phagocytoides Gauducheau.
10. Paramœba hominis Craig.
†11. Cercomonas hominis Davaine.
12. Trichomonas intestinalis Leuckart.
13. Lamblia intestinalis Lambl.
14. Eimeria stiedæ Lindemann.
15. ,, hominis R. Blanchard.
16. Isospora bigemina Stiles.
17. Chilodon dentatus Dujardin.
18. ,, uncinatus.
19. Colpoda cucullus Guiart.
20. Balantidium coli Malmsten.
21. ,, minutum Schaudinn.
22. Nyctotherus faba Schaudinn.
23. ,, giganteus P. Krause.
24. ,, africana Castellani.

(*b*) **Trematoda.**

25. Cladorchis watsoni Conyngham.
26. Gastrodiscus hominis Lewis and McConnell.
27. Fasciolopsis buski Lankester.
28. ,, fülleborni Rodenwalt.
29. Kwan's fluke Heanley.

‡30. Heterophyes heterophyes von Siebold.

(*c*) **Cestoda.**

31. Dibothriocephalus latus Linnæus.
32. ,, cordatus Leuckart.
33. ,, parvus Stephens.
34. Diplogonoporus grandis Blanchard.
35. Dipylidium caninum Linnæus.
36. Hymenolepis nana von Siebold.
37. ,, deminuta Rudolphi.
38. ,, lanceolata Bloch.

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* The following Entamœbæ must be added : *E. minuta* Elmassian 1909 ; *E. nipponica* Koidzumi 1909.

† The following flagellates must be added : *Bodo zeylanicus* Castellani and Chalmers 1909.

‡ *Fasioletta ilocana* must be added.

39. Davainea madagascariensis Davaine.
40. ,, asiatica von Linstow.
41. Tænia (Tænia) solium Linnæus.
42. ,, (Tæniorhynchus) saginata Goeze.
43. ,, ,, africana von Linstow.
44. ,, ,, hominis von Linstow.
45. ,, ,, philippina Garrison.
46. ,, (?) confusa Ward.
47. ,, (?) bremneri Stephens.

(*d*) **Nemathelminthes.**

48. Strongyloides stercoralis Bavay.
49. Trichinella spiralis Owen.
50. Trichuris trichiura (Linnæus).
51. Strongylus gibsoni Stephens.
52. Trichostrongylus instabilis Railliet.
53. ,, probolurus Railliet.
54. ,, vitrinus Looss.
55. Agchylostoma duodenale Dubini.
56. Necator americanus Stiles.
57. Triodontophorus deminutus Railliet and Henry.
58. Œsophagostoma brumpti Railliet and Henry.
59. Physaloptera caucasica von Linstow.
50. ,, mordens Leiper.
61. Ascaris lumbricoides Linnæus.
62. ,, texana Smith and Goethe.
63. ,, maritima Leuckart.
64. Toxascaris canis Werner.
65. Belascaris mystax Zeder.
66. Oxyuris vermicularis Linnæus.
67. Gordius aquaticus Linnæus.
68. ,, chiliensis Blanchard.
69. Paragordius varius Leidy.
60. ,, tricuspidatus Dufour.
71. ,, cinctus von Linstow.
72. Parachordodes tolosanus Dujardin.
73. ,, pustulosus Baird.
74. ,, violaceus Baird.
75. ,, alpestris Villot.
76. Echinorhynchus hominis Lambl.
77. Gigantorhynchus gigas Goeze.

(*e*) **Crustacea.**

78. Gammarus pulex.

(*f*) **Diplopoda.**

79. Julus terrestris Linnæus.
80. ,, londinenensis Leach.
81. Polydesmus complanatus.

(*g*) **Chilopoda.**

82. Geophilus electricus Linnæus.
83. Scutigera coleoptrata.
84. Chætechelyne vesuviana.
85. Himantarium gervaisi.
86. Stigmatogaster subterraneus.

(*h*) **Diptera (Larvæ only).**

87. Sarcophaga magnifica Schiner.
88. ,, affinis.
89. ,, carnaria Linnæus.

90. Sarcophaga hæmorrhoidalis.
91. ,, hæmatodes Joseph.
92. Lucilia cæsar Linnæus.
93. ,, regina Maly.
94. Fannia canicularis Linnæus.
95. ,, desjardensii Macquart.
96. ,, scalaris.
97. ,, incisurata.
98. ,, manicuta.
99. ,, saltatrix.
100. Musca corvina.

(*i*) **Coleoptera (Larvæ).**

101. Several described, but species not determined.

A number of these parasites, however, have not been recorded in the tropics, and others are believed to be non-pathogenic.

Statistical information with regard to the prevalence of the various forms in different tropical regions is still wanting, but some valuable observations have been made, especially in the Philippine Islands. The relative prevalence of the various intestinal parasites in these islands has been carefully studied by Garrison, who finds that 84 per cent. of the investigated persons were infected with fifteen genera and about twenty species, multiple infections being the rule, the average number of infections being 2·25 per head.

The prevalence of the various parasites was as follows:

	Per Cent.
Trichuris	59·0
Agchylostoma and Necator	52·0
Ascaris	26·0
Entamœbæ	23·0
Flagellates and Ciliates	21·0
Strongyloides	3·0
Oxyuris	0·8
Tæniæ	0·7
Schistosomum japonicum	0·6
Paragonimus	0·4
Opisthorchis	0·3
Hymenolepis	0·1

Besides these, however, there were a number of undetermined forms. The infection with *Trichuris* is variously given in different countries—*e.g.*, Porto Rico (Commission), 7·27 per cent.; India (Fearnside), 6·95 per cent.; India (Dobson), 4·4 per cent.; Central Africa (Daniels), 2·79 per cent. The infection with *Agchylostoma* and *Necator* is given in India (Calvert), 83 per cent.; (Dobson), 57·58 per cent.; (Fearnside), 65·83 per cent. *Ascaris* infection in West Africa (Wellman) is 50·97 per cent. Garrison considers his figure of 26 per cent., which is based upon adults only, as much too low. *Strongyloides* is placed in Central Africa at (Daniels) 1·5 per cent.; West Africa (Wellman), 0·65 per cent.; Porto Rico (Commission), 0·8 per cent. *Oxyuris* is given in India (Dobson) at 15·37 per cent.

DISEASES CAUSED BY ANIMAL PARASITES.

The pathogenicity of these intestinal parasites must now be considered. In Chapter XI. we drew attention to the *Entamœbæ* infecting the mouth and the alimentary canal, and need not repeat what has already been written. Dysentery, it will be remembered, can be caused by *Entamœba histolytica* and *E. tetragena*.

Diarrhœa or dysenteric-like conditions may be caused by flagellate organisms—*e.g.*, *Cercomonas hominis*, *Trichomonas intestinalis*, and *Lamblia intestinalis*. *Eimeria stiedæ* and *E. hominis* may also cause diarrhœa.

Diarrhœa and dysentery can also be produced by ciliate organisms—*e.g.*, *Chilodon dentatus*, *C. uncinatus*, *Colpoda cucullus*, *Balantidium coli*, and perhaps *B. minutum*, *Nyctotherus faba*, and *N. giganteus*. With regard to these flagellates and ciliates more will be said later in the chapter on Dysentery and Diarrhœa.

Diarrhœa has been described as being caused by *Cladorchis watsoni*, while *Fasciolopsis buski* causes dysenteric diarrhœa, *F. rathouisi* colic, *C. fülleborni* fever, and Kwan's fluke gastric disturbance. The presence of trematode worms can only be diagnosed by the discovery of the eggs or the adult, and the treatment must be on the same lines as that described for agchylostomiasis.

Schistosomum mansoni is the cause of intestinal bilharziosis, which will be described later.

Cestode parasites cause gastric and reflex symptoms, mostly of a vague nature. The former comprise salivation, diarrhœa, or constipation, with colicky pains, nausea, vomiting, or dyspepsia, while the latter include faintness, unequal pupils, disorders of vision and hearing, headache, itching of the nose or anus, vertigo, epilepsy, etc. Anæmia and skin eruptions have also been recorded. The treatment is the usual anthelmintic remedy of *Filix mas*, in capsules (six 10-minim capsules) or emulsions (olei filicis ʒi., gummæ acaciæ q.s., syrupi zingiberis ʒi., aquæ ad ℥ii. Fiat haust.), followed by a saline purgative six hours later.

The infections by the nemathelminthes require rather longer descriptions—*e.g.*, strongyloidosis, trichuriasis, agchylostomiasis, ascariasis, and oxyuriasis, which are important diseases in the tropics.

Strongyloidosis.

Strongyloidosis, usually called intestinal anguillulosis, is the infection of man with *Strongyloides sterocoralis* Bavay 1876, which produces no symptoms if present in small numbers, but induces an intestinal catarrh leading to anæmia and an intermittent diarrhœa when in large numbers. The disease is met with all over the tropical world, and even in the temperate zone. Diagnosis can only be effected by finding the rhabdite embryo (the so-called

Anguillula stercoralis), or the eggs in the fæces, in which the latter will only be found when violent diarrhœa is present. The treatment is the same as for agchylostomiasis (see p. 404).

Trichuriasis.

Synonyms.—Whip-worm Infection, Trichocephaliasis.

Nomenclature.—Büttner in 1761 first named the worm *Trichuris*, or thread-tail, for he mistook the posterior end for the anterior. Linnæus in 1771 called the worm *Ascaris trichiura*, but Goeze in 1782 changed the name to *Trichocephalus trichiura*, because he recognized the error made by Büttner. The term *Trichuris trichiura* Linnæus must, however, stand, and the term for any disease associated with this worm must be 'trichuriasis.'

Definition.—Trichuriasis is an infection of the large intestine, appendix, or ileum by *Trichuris trichiura* Linnæus 1771, which produces no symptoms unless it is present in large numbers, when anæmia, nervous and gastro-intestinal symptoms may appear.

History.—From the time of Barth, who, in 1845, was the first to ascribe a pathogenic rôle to the worm, there have been a large number of observers who have considered it to be the cause of gastro-intestinal and nervous symptoms, while Metchnikoff and Guiart in 1901 considered it to be a cause of appendicitis. In the same year Girard drew attention to the possible transmission of pathogenic bacteria into the tissues via the wounds produced by the worm. In 1902 Schiller ascribed a case of high fever to the action of a heavy infection with the parasite. In 1908 Musgrave, Clegg, and Polk contributed an excellent monograph on the whole subject of trichuriasis, together with full accounts of four cases. Our own experience is in favour of the worm being occasionally directly the cause of appendicitis, for several times we have found it in the inflamed appendix removed by operation.

Geographical Distribution.—*Trichuris trichiura* is cosmopolitan in its distribution.

Ætiology.—Trichuriasis is caused by *Trichuris trichiura* Linnæus 1771, which, as far as is known, is really a parasite of man and monkeys, while allied forms exist in other animals. The eggs escape with the fæces, and require three to six months for the development of the embryo, which can then remain alive for years inside the shell if kept on moist earth. Usually the eggs gain access to man by means of contaminated food, especially uncooked vegetables, and to a less extent fruits. This is especially likely to occur in the tropics, where human fæcal matter is often allowed to be deposited in vegetable gardens. Musgrave, Clegg, and Polk report finding the ova in washings from fresh vegetables. Domestic animals, insects, dust, etc , are also considered to be possible means of infection. When taken into the alimentary canal, it hatches and reaches sexual maturity in sixteen days.

It occurs more commonly among children than adults, women than men, and native races than European. But all these factors appear simply to depend upon good or bad sanitation, for the latter is the principal factor in producing infection.

Pathology.—It is believed that the worms attached themselves to the mucosa of the bowel by the head penetrating deeply into its tissue either via a gland or directly. In this position the worm is firmly fixed, and is more or less protected against the action of anthelminthics. They do not appear to be blood-suckers, nor is there any evidence that they produce toxins—at all events, in sufficient quantity to affect man. On the other hand, it is believed that micro-organisms can gain entrance to the blood through the wounds produced by the head, and this secondary infection may be the cause of the appendicitis and other pathological phenomena.

Morbid Anatomy.—A post-mortem simply reveals anæmia and dropsy, with at times appendicitis. The most marked feature is the presence of large numbers of *Trichuris trichiura.*

Symptomatology.—The symptomatology may be subdivided into the intestinal and appendicular varieties.

Intestinal Variety.—The illness begins with dizziness, tinnitus aurium, and a sensation of weakness, which may be followed by slight daily fever and later by œdema of the face and extremities, while anæmia appears and gradually progresses. Seen at this stage of the illness, the mucosa of the lips and tongue appear pale, the appetite is poor, and dyspepsia, followed later by nausea and vomiting, with or without slight diarrhœa, occurs.

The liver and spleen are normal, but a hæmic murmur may be heard at the apex of the heart, while the blood examination reveals a great decrease in the number of red cells and the presence of poikilocytes, but no nucleated elements. The hæmoglobin is also reduced, while the leucocytes are increased, and also in most cases there is an absence of an eosinophilia. The urine is normal. There is mental depression, restlessness, headache, and at times insomnia. As the disease progresses the anæmia becomes more and more marked, and death may eventually ensue.

Appendicular Variety.—The symptoms of this variety are the same as those for appendicitis arising from other causes. Operative treatment reveals the nature of the malady.

Diagnosis.—The disease closely resembles agchylostomiasis, from which it may be differentiated by finding trichuris ova and no agchylostome ova in the fæces, and also by the absence of marked eosinophilia.

Prognosis.—The ordinary slight infection which is frequently met with may be considered to be harmless, but the prognosis is grave in those rare cases of very heavy infection presenting the symptoms described above.

Treatment.—The treatment at present advised is the administration of thymol by the mouth in the manner presently to be described for agchylostomiasis, and to give enemata of solutions of benzine.

Prophylaxis.—Good sanitation and proper disposal of sewage, associated with cleanliness in the preparation of food, as well as with personal cleanliness, constitute important prophylactic measures. Uncooked vegetables and skins of fruits should not be eaten.

Agchylostomiasis.

Synonyms.—Anchylostomiasis, Miner's Anæmia, Ankylostomiasis, Ceylon Anæmia, Uncinariasis, Negro Consumption, Dochmiasis, Cachexie Africaine, Egyptian Chlorosis, Anémie des Pays Chauds, Tropical Chlorosis, Mal de Cœur, Hook-worm Disease, Tunnelkrankheit, Geophagia, Allotriophagia, Anchylostomiasi, Sufura, Tuntum.

Definition.—Agchylostomiasis is a toxæmia resulting in a progressive anæmia, caused by *Agchylostoma duodenale* Dubini 1843 and *Necator americanus* Stiles 1902.

History.—The history of the discovery, together with the structure, life-history, and geographical distribution of the two parasites, has been described in Chapter XVI., and it now remains to give an account of the disease produced by them in man.

Climatology.—The disease will be found wherever there is a suitable temperature and moisture for the development of the parasites. It is therefore spread throughout the tropics of America, Africa, and Asia, and is also found in Queensland, New Guinea, and Fiji, and also in mines or tunnels in Europe, where the conditions of temperature and moisture resemble the tropics.

Ætiology.—The disease is due to the presence of *Agchylostoma duodenale* and *Necator americana* in the body. The infection by these parasites takes place by two routes, either through the skin or by the mouth. In the latter instance it is generally acquired by eating contaminated vegetables, or through the habit some natives have of geophagy. It is possible that the pathological phenomena may be due to toxins, either set free by the embryo in its travels from the skin to the alimentary canal, or inoculated into the blood-stream from the cephalic glands of the adult worm as it grips the villi of the intestine. But absolute proof is still required of the presence of these toxins, notwithstanding the work of De Giovanni, Gabbi, Alessandrini, and many others. The Porto Rico Commission confirms the suspicion which had long existed as to a relative racial immunity, finding 71 per cent. of the cases in Europeans, 54 per cent. of the cases in mulattoes, and 41 per cent. of the cases in negroes, to vary from medium to very severe, though the degree of infection of the three races was in the proportions of 78 per cent., 72 per cent., and 76 per cent.

Pathology.—When the embryos enter the skin in sufficient numbers they cause an eruption of papules or vesicles, but these are more probably due to the pyococci and bacteria introduced along with larvæ, which are the true cause of the dermatitis. These skin lesions are called 'bunches' in Cornwall, 'mazamorra' in Porto Rico, and 'ground-itch' in Assam.

It is not known what effect the journey from the skin to the alimentary canal has upon the host, but it is certain that in course of time a marked effect upon the blood and the organs of the body is produced, which often appears out of proportion to the number of worms which can be found in the intestine. Loeb and Smith find that the worm produces a substance which hinders the coagulation of the blood. Some observers—*e.g.*, Gabbi—have found that the blood of agchylostome patients is more toxic than the blood of healthy people, and contains more hæmolytic substances, but this has been denied by Marini. Padoa and others have observed that the processes of intestinal putrefaction are very marked in agchylostomiasis.

Morbid Anatomy.—An eruption about the feet, œdema about the ankles, with a peculiar dead-white appearance of the conjunctiva, are often seen on the post-mortem table. On opening the abdomen, it will be noted that the tissues are damp, the peritoneum sodden, the intestines very pale, and some straw-coloured fluid will generally be seen in the peritoneal cavity. All the organs appear damp and pale. The lungs are œdematous, the heart pale and fatty, with sometimes hypertrophy of the left ventricle. The liver is fatty; the spleen presents various appearances, but generally is shrunken; the pancreas is normal, as are the suprarenals; the stomach shows chronic gastritis; the jejunum and ileum are usually contracted; and the mucosa is often dark red in colour, and marked by small hæmorrhagic points, which indicate the position of the bites. The agchylostomes may be found in large numbers, or may require considerable looking for. Sometimes they are firmly attached to the mucosæ. The kidneys are usually enlarged, pale, and fatty.

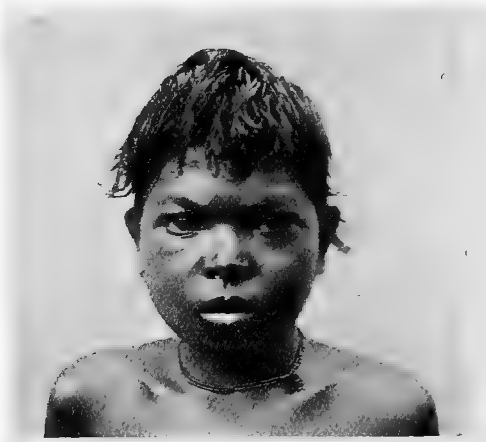

FIG. 332.—CASE OF AGCHYLOSTOMIASIS. Note the swollen face.

Symptomatology.—The first stage or invasion of the body by the embryos may be marked by dermatitis of various types, papulo-vesicular or pustulo-ulcerative. The second stage is the development of a leucocytosis and an eosinophilia before the definite disease begins. The third stage is when the anæmia begins to be appreciable.

The patient becomes pale, weak, and dropsical, the pallor being most marked in the conjunctiva of the lower eyelid, which becomes of a peculiar dead-white appearance. The emaciation may be marked, but, on the other hand, it may be concealed by the dropsy. In many cases there is œdema round the ankles, and in others there may be general œdema, with often ascites, œdema of the legs, scrotum, or face. When the ascites is marked, the patient has a protuberant abdomen, and looks at first sight not unlike a person suffering from malarial cachexia or kala-azar. The tongue is said by some observers to have two purplish smears, one on each side of the median line, and to be pigmented, but this in our experience can be seen in normal natives. The appetite may be perverted and geophagy result, and in addition there are signs of dyspepsia due to the chronic gastritis, and there may be nausea, vomiting, heartburn, and pain over the pit of the stomach. The bowels may be constipated, or there may be diarrhœa. Ova of *Ascaris* and *Trichuris*, together with those of *Agchylostoma*, are often seen in the fæces. Occasionally a little blood and mucus are present, and Charcot-Leyden crystals may also occur.

Blood.—There is marked anæmia, which has been shown by Boycott and Haldane, by using Haldane and Lorrain-Smith's method of estimating the total volume of the blood, to be due to a hydræmia—that is to say, the total volume of the blood is increased without a corresponding increase in the cellular elements and hæmoglobin. This is analogous to the blood condition found in chlorosis, and is the reverse of that found in pernicious anæmia, the features of which are very rarely met with in agchylostomiasis.

The counts given by different observers vary. Thus, Ashford gives as the average of nineteen cases the following figures: Erythrocytes, 1,776,000; hæmoglobin, 21 per cent.; colour-index, 0·6; leucocytes, 7,000; eosinophiles, 10·3 per cent. Boycott and Haldane in seventeen cases found erythrocytes from 4,072,000 to 1,533,000; hæmoglobin from 58 to 17 per cent.; colour-index from 0·71 to 0·56; leucocytes from 44,800 to 3,800; polymorphonuclears, 48·7 per cent.; lymphocytes, 14·4 per cent.; mononuclears, 5·9 per cent.; transitionals, 7·4 per cent.; eosinophiles, 23 per cent.; mast cells, 0·6 per cent. Ashford, King, and Gutierrez found erythrocytes from normal to 754,000; hæmoglobin from 8 to 101 per cent.; leucocytes from 5,000 to 10,000; polymorphonuclears, 54·5 per cent.; lymphocytes, 16·3 per cent.; mononuclears, 8·6 per cent.; eosinophiles, 17·1 per cent.; other forms, 3·5 per cent.

The red cells may show pathological changes and poikilocytes; megalocytes and polychromasia may be seen, as well as normoblasts and megaloblasts. The diminution of the colour-index is said to be the first pathological sign in the blood. In some very rare cases a condition of hyperglobulia has been observed instead of the usual oligocæmia.

Boycott has shown that the principal leucocytic changes are to be seen in the blood before a condition of marked anæmia has set in, when it is found that there may be high leucocytosis—20,600 to 56,000—with a very high eosinophile figure of 56·2 to 66·2 per cent., while the hæmoglobin was from 98 to 80 per cent. When anæmia sets in, a leucocytosis is much less frequent, being met with in cases in which anæmia develops quickly. On the other hand, a leucopenia may be seen if the case is very anæmic. The reason for this alteration from a high state of leucocytosis without anæmia to that of leucopenia with severe anæmia might at first sight be thought to be explicable by the hydræmia producing the anæmia. Boycott, however, considers that this is not so, for he points out that leucocytosis can occur with marked anæmia, and that there is always a tendency on the part of the blood to restore its average volume and composition when altered from the normal, and comparing the normal leucocytic count of the hydræmia of chlorosis, says that, if there was no other factor, the leucocytic count of agchylostomiasis would not be affected by the hydræmia.

He thinks that the true explanation is probably exhaustion of the bone-marrow, produced by the anæmia, and partially due to a failure on the part of the individual to react to the stimulus to produce the eosinophile leucocytes. In any case, the leucocytic reaction does not bear any relationship to the anæmia. According to Boycott and Haldane, if the eosinophiles are deducted from the total number of the leucocytes, and the percentage of the remainder then calculated, it will be found to be nearly normal. The eosinophilia has been found to remain after the ova have quite disappeared from the fæces. Any inflammatory complication which leads to a polymorphonuclear increase may hide the true eosinophilia. The leucocytes are normal in structure, a few neutrophile, but no eosinophile myelocytes are to be seen. Wemberg and Mello have shown that the injection in guinea-pigs of extract of various worms induces a certain degree of eosinophilia.

Reviewing this description of the blood, we would point out that it looks as though toxins were stimulating the production of the eosinophiles, and at the same time preventing a proper formation of hæmoglobin, and finally producing the hydræmia. As a result of the diminution of the production of hæmoglobin, the iron in the liver is diminished.

Patients often complain of palpitation or difficulty in breathing. The lungs will be found normal, but the heart may be displaced downwards and to the left, and be feeble, with a hæmic bruit at the base. The vessels of the neck may be seen to pulsate markedly. The pulse is quick, and may be weak, thready, dicrotic, and intermittent. The liver is very often enlarged, especially in children.

In many cases there is no fever; in others a low fever, often of an intermittent type, is present. Among the agchylostomiasis patients of the Colombo clinic, 20 per cent. had a low intermittent or remittent fever. There is much diversity of opinion as to the origin of this fever, which, according to the researches of one of us, are —at all events, in some cases—due to secondary infections from intestinal bacteria, which probably enter through the minute wounds caused in the intestinal mucosa by the worms. In several cases this low fever continues long after the patient has got rid of the agchylostome under adequate treatment.

The urine is copious, pale, and often alkaline, with a specific gravity varying from 1010 to 1015. Albumin is rarely seen, but there is an increase of indigo-blue and urobilin, and there is said to be albumosuria at times. The excretion of nitrogen is said to be much increased. Lussana believes that there are toxins in the urine which can be separated by the following method: The urine is condensed in a water-bath at 60° C. to 70° C. to a syrup, and then extracted with absolute alcohol, which is driven off, and the residue dissolved in sterilized water, and injected subcutaneously into rabbits.

This is believed to produce diminution of the red corpuscles, loss of hæmoglobin and poikilocytosis, which speedily disappear on stopping the injections. These findings of Lussana have been confirmed by some and refuted by other observers.

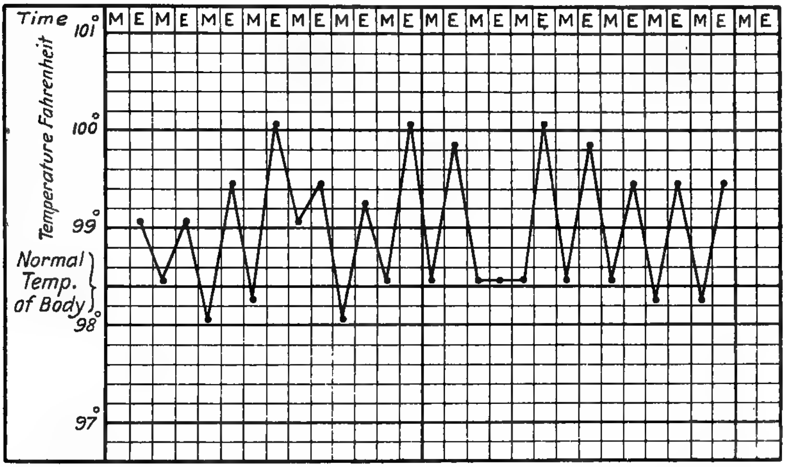

FIG. 333.—TEMPERATURE-CHART OF A CASE OF AGCHYLOSTOMIASIS FEVER.

From a case in the Clinic for Tropical Diseases.

Mental and physical hebetude are marked, and other nervous symptoms may be observed. Children do not develop properly, and sterility, with delayed menstruation, has been noted.

Complications.—Any intercurrent disease is a serious complication, as also is pregnancy.

Diagnosis.—The diagnosis of early cases, before the development of the anæmia, depends upon finding the ova in the fæces.

Anæmia in tropical countries, especially if associated with dropsy, should at once lead the practitioner to suspect agchylostomiasis. It must be remembered, however, that it is by no means easy to find the ova in the fæces at the first examination, and that sometimes, even in the worst cases, they require to be looked for.

Occasionally it is useful to give an aperient to make the eggs appear in the stools.

Prognosis.—There is no doubt that agchylostomiasis is one of the great factors in producing the death-rate of a tropical native community, very often because it is not diagnosed. Ashford, King, and Gutierrez placed the deaths of Porto Rico caused by agchylostomiasis at 30 per cent. of the total death-rate, and we are not at all surprised at this, for our experience indicates that the disease is frequently entered in death certificates as anæmia, general dropsy, and malarial cachexia.

Treatment.—The aim of the treatment is to kill and remove the parasites, and this can be effected by thymol, eucalyptus oil, eucalyptol, beta-naphthol, or male-fern. A case must not be considered cured until the fæces show no ova on repeated examination after two or three weeks.

In all cases the patient should be carefully examined as to the condition of all his organs before treatment is begun, and should be placed on low or liquid diet for a day or so, and while being treated should be kept in bed, and care taken that the bowels have been well opened.

Thymol, introduced by Bozzolo, should be given in cachets, or as an emulsion. Generally 15 to 30 grains are given, and two hours later another 15 to 30 grains, followed in some cases by a third dose of 15 to 30 grains after another two hours. If the bowels do not act within four hours of the last dose, a saline aperient should be given. The treatment may be repeated on the following day.

Thymol is a very poisonous drug in large doses, causing first irritation of the cerebral centres, with excitement and vertigo, while a dark colour may appear in the urine, or, according to Blum, may be produced by the addition of hydrochloric acid to the urine. According to the same authority, this colour exists in the form of a chromogen in the urine, the chemical nature of which is threefold: thymolsulphuric acid, thymolhydrochinon sulphuric acid, and thymolglycuronic acid. In larger doses the nerve centres are paralyzed, the blood-pressure falls, and the patient dies of collapse.

Thymol, however, is very insoluble in water—only 1 in 1,500 of cold water —but it is easily soluble in alcohol, ether, chloroform, glycerine, and turpentine; hence no stimulant whatever must be given to a patient who is to take or has taken thymol, and not merely must care be taken not to order stimulants, but the nurses must be warned of the danger of giving them. Thymol is also soluble in oil. Hence no purgative of castor oil should be ordered after its administration. Thymol certainly should never be given if there is marked visceral disease, nor do we think that it should be given in very profound anæmia—*i.e.*, when the number of red cells is below 1,500,000 per cubic millimetre. It is, however, very satisfactory in its lethal action on the worms, but the treatment must be repeated in many cases in a week, and again repeated if ova are seen in the fæces.

Eucalyptus Oil and Chloroform.—A much less dangerous treatment is by oil of eucalyptus and chloroform, which should be preceded by a saline purgative given a few hours earlier.

The usual formula is :

Olei eucalypti	♏xxx.
Chloroformis	♏xlv.
Olei ricini	ʒx.

One half to be given first thing in the morning, and the other half in half an hour. The chloroform is probably the active principle of this mixture. It does not work as satisfactorily as thymol, but it is safer, and can be used several days in succession. We use it often in children and debilitated adults, for it certainly should be used in any case in which thymol is contra-indicated. Some physicians prefer eucalyptol instead of the oil of eucalyptus. The difference is that eucalyptol is that portion which passes over between 347° F. to 351° F. when the oil is being distilled from the leaves.

Beta-naphthol can be given in cachets in 15-grain doses, administered in the same manner as thymol—viz., one cachet every two hours for two or three times, with the same precautions as with thymol.*

Male-fern, followed by castor oil, or calomel, or infusion of senna, has also been strongly recommended, and was generally used before Bozzolo introduced thymol in 1880. The Porto Rico Commission found it useless even in doses which produced toxic symptoms.

Prophylaxis.—Prophylaxis must be based upon an attempt to kill the parasites in the human being, and to prevent the infection of the human being by the parasite.

The first method is the most feasible, and has been tried on a large scale at Porto Rico, and on many estates and in mines. The quickest method is to examine the people for anæmia, and treat the anæmics with thymol, the eucalyptus-oil mixture, or beta-naphthol, after the examination of the fæces. On estates the method of examining the blood of non-anæmic persons for an eosinophilia might be adopted, as the worms may be present before the anæmia shows itself. The fæces of persons showing eosinophilia should then be examined for ova, and treatment instituted on the findings. Of course a certain degree of eosinophilia is also present in cases of ascariasis and other kinds of helminthiasis.

With regard to the second method, the formation and use of proper latrines may do much. With regard to estates, tea-bushes, etc., should not be allowed to grow right up to the coolies' lines, but a clear area should be left, and this should be treated from time to time with quicklime. Further, every alternate row of bushes might be left out in the half-acre adjoining the lines, and in the vacant spaces latrine-holes lined with lime might be dug. The use of bucket-latrines and the destruction of the fæces in a small crude incinerator would be better, and could be easily managed on estates. The best cheap latrine is 'Bailey's patent,' manufactured by the Empire Engineering Company of Cawnpore, at a cost of 118 rupees for a two-seat, and 360 rupees for an eight-seat latrine.

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* In debilitated patients beta-naphthol may be given in 5-grain pills made up with pulvis tragacanthæ composita and syrup. One to three pills, according to age, should be administered early in the morning on six successive days. No preliminary preparation is necessary.

The figures show small incinerators in use in a mill and in a gaol in Colombo, but it must be remembered that fæces require a considerable amount of fuel and a considerable draught before they are properly burnt. There is, however, no need to go to great expense, and a simply-constructed incinerator will often work well, if a little smell is not objected to. In order to calculate the size of latrine required, it must be remembered that an Indian community is estimated to pass 8 ounces of fæcal matter per diem in a mixed population of races, sexes, and ages, and 40 ounces of urine. The usual size of a galvanized iron latrine-bucket is 14 inches high by 12 inches broad at the mouth and 9 inches at the base, and it has a cubic capacity of 0·9 cubic foot, and is said to weigh 10 pounds when full. Coir fibre is often mixed with the fæcal matter in the proportion of 2½ pounds of coir to 1 pound of fæcal matter or 1 gallon of urine.

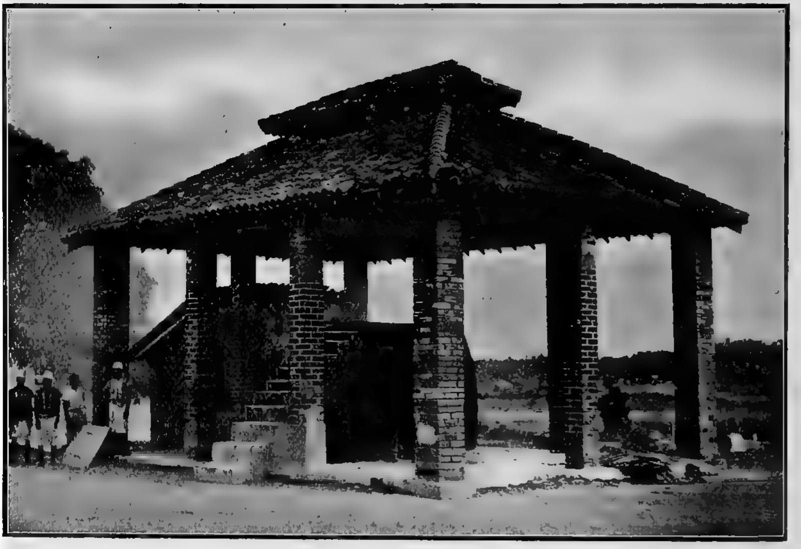

FIG. 334.—A CHEAP AND EASILY CONSTRUCTED INCINERATOR.

Messrs. Freudenberg and Company, of Colombo, use a simple incinerator, and they have kindly supplied us with the following details of their process, which is carried out at night:

Average number of buckets of fæcal matter burnt per night, 20.
Average weight contents of a bucket, 26 pounds.
Average quantity of ash left after burning the above, 5 buckets.
Average amount of coir dust used per bucket, 2 pounds.

Average amount of firewood used per burning, 2 hundredweight.

Average amount of rubbish burnt at the same time, together with a few old gunny bags, 1½ hundredweight.

Average number of coolies whose fæcal matter is dealt with, 400.

Latrine coolies at 62½ cents per diem to do the work, 2.

Firing starts at 7 p.m., and is finished by 8 a.m.; the highest temperature recorded was 1,050° C.

The urine can, of course, be separated from the fæces by using a Donaldson's separator latrine. The urine can then be disposed of by burial, and the fæces burnt.

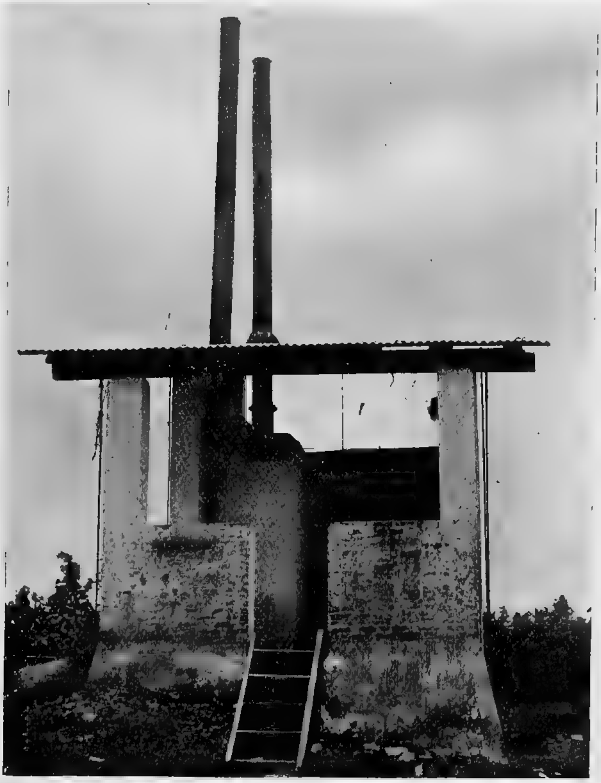

FIG. 335.—ANOTHER CHEAP AND EASILY CONSTRUCTED INCINERATOR.

There is no doubt that some such method would have excellent results in dealing with the problem in small communities and estates if carried out properly.

Badly infected lands might be treated with lime. It has been recommended that coolies should protect their feet by first dipping them in a bucket of tar, and then in one with sand.

The method of dealing with a large community is best exemplified by quoting the excellent work of the two Porto Rico Commissions, temporary and permanent, the former consisting of Ashford, King, and Igaravdez, and the latter of Igaravdez, Martinez, and Sein y Sein.

Patients attend at a central, or one of the outlying depots or dispensaries, where their stools are examined, and they are given medicines, and card with the following instructions :

1. Take one of the two purgatives given to you to-night (sodium sulphate).
2. Take at 6 a.m. to-morrow half the capsules [all the capsules equal 45 to 60 grains (3 to 4 grammes) of thymol, or 23 to 45 grains (1·5 to 3 grammes) of β-naphthol].
3. Take the other half at 8 a.m. the same morning.
4. Take the other purgative at 10 a.m.
5. You should neither drink wine nor any alcoholic liquor during the time you are taking these medicines.
6. Come for more medicines until the physician says you are cured.
7. Have a privy in your house. Do not defecate on the surface of the ground, but in the privy.
8. Do not walk barefooted, so that you may avoid catching mazamorra in your feet. Wear shoes, and you will never suffer from anæmia.

In addition, farmers were requested to stop the pollution of the ground, and to introduce the use of shoes.

The result was that 11 per cent. of the population were treated in the year 1906-07 (89,233), and of these, 25·7 per cent. were cured, 17·4 per cent. practically cured, 40·5 per cent. were under treatment, 16·2 per cent. ceased to return, and 0·2 per cent. died, at a total cost of £9,600, of which £7,200 went in salaries and £1,100 in drugs.

Again, the highest credit must be given to the Americans for the fearless way in which they spend money on the prevention of disease, and the free hand which they give to the sanatarian in the tropics.

Ascariasis.

Definition. — Ascariasis is infection with *Ascaris lumbricoides* Linnæus 1758, *Toxascaris canis* Werner 1782, or *Belascaris mystax* Zeder 1800, the first named being much the most common.

Symptomatology.—The symptoms may be nil, or may resemble those of cestode infections, being partly gastro-intestinal, partly reflex, while skin irritation and eruptions may also be present. If, however, the number of parasites be very considerable, signs of toxic poisoning, or even of intestinal obstruction from interlacing of the worms, may develop, but the great danger is from the wandering of the parasites. If they wander up the bile-duct and into the liver, they may cause abscesses in the liver. We have found as many as eleven worms in the bile-duct, with a large number in the liver, three of which lay in abscess cavities. They may also enter the duct of Wirsung, and cause slight inflammation of the pancreas, or go into the appendix, and cause appendicitis. Further, they may pierce the bowel in cases of ulcerative conditions of the bowels, and enter the peritoneum or the bladder, or enter the lung, the nose, or the ear by the Eustachian tube—in fact, they may wander all over the body. The observer must, however, be careful to distinguish between the post-mortem and ante-mortem wanderings of these worms; in the former case the worms are generally found alive. The most important reflex symptoms are the convulsions so commonly met with in children. We have seen cases of fever resembling typhoid (typho-lumbricosis) which on post-mortem examination have shown no lesions of typhoid, but enormous numbers of ascaris.

Diagnosis will depend upon the discovery of the eggs in the fæces.

Treatment.—The best treatment is santonin, with some form of purgative. Usually santonin is mixed with an equal quantity of calomel, and given in doses of 1 to 3 grains for an adult, and $\frac{1}{6}$ grain for every year of life for a child. The dose is given every morning for two or three days, and repeated again in a week if eggs still appear in the fæces. It is as well to remember that santonin may cause blue or yellow vision.

Oxyuriasis.

Definition.—Oxyuriasis is infection with *Oxyuris vermicularis* Linnæus 1767, and is common all over the world.

Symptomatology.—The symptoms are irritation in the region of the anus, with sometimes a distinct entero-colitis, and sometimes slight fever. It is usually stated that there is a sense of irritation in the nose. The diagnosis is to be made by finding the worms in the motions after a purgative. In girls the worms may enter the vagina and cause vaginitis.

Treatment.—The gravid females can be killed by rectal injections of quassia, but the young forms require internal treatment with santonin and calomel, as described under Ascariasis. Flynn recommends sulphur (gr. iii.) three times a day in adults, and gr. i.ss. in children, given as a cachet or lozenge. A 10 to 20 per cent. calomel ointment may be applied to the anus, or iodoform and naphthalin suppositories may be used.

Gordiacea and Acanthocephala.

Infections with species of the Gordiacea and Acanthocephala are rare. Treatment would be on the same lines as ' ascariasis.'

Diplopodiasis and Chilopodiasis.

Diplopodiasis and chilopodiasis are rare and unimportant, giving rise to intestinal pains and diarrhœa. The diagnosis is only possible on discovery of the parasites in the fæces. The treatment is the chloroform mixture, as for agchylostomiasis.

Myiasis.

Myiasis is also comparatively unimportant. It causes intestinal disturbances, diarrhœa and abdominal pains, as already described in Chapter XX. Only the discovery of the larvæ makes the diagnosis possible. The treatment is castor oil.

Scoleciasis.

Scoleciasis is the infection with the larvæ of beetles, and is very rare.

The Vomiting Sickness of Jamaica.

Under this heading Turton, in 1904, described a disease of children in the West Indies which, apparently, he considered to be a separate pathological entity. Recently Branch has given an account of the same disease, but regards it rather as a series of symptoms which, if full investigation were possible, might be found to be merely those of some known disease.

The ætiology is unknown, and the post-mortem appearances are merely those of enlargement of the vessels of the brain and spinal cord, hypostatic congestion of the lungs, congestion of the mucosæ of the stomach and intestines, with the presence of a dark slimy substance in the lumen.

The disease is found in children from a few months up to nine to ten years of age, and usually in the months of December to March. It attacks more than one member of a family as a rule, and is apparently always associated with Ascarides.

The history appears to be as follows: Somewhere about midnight a child wakes up, and complains of pains in its stomach, and in a little time it vomits its last meal. This gives temporary relief, but sooner or later the vomiting commences again, and consists of frothy mucus, accompanied at times with fever. Usually the patient recovers, but not unfrequently the child passes into a state of collapse, with cold sweats, weak, rapid pulse, and shallow, irregular respirations, and death ensues, being preceded by convulsions.

The best treatment is santonin and calomel, followed by quinine.

Earth-Eating.

Synonyms.—Geophagy, Mal d'estomac (French).

Earth-eating is common in many parts of the tropics, especially in children and pregnant women. It is believed to be acquired by the children being left to crawl about and eat anything which comes to hand. It is also acquired by being taken as a remedy for syphilis and other diseases.

Christopherson says that it is common in the Sudan, where two forms of earth are eaten: (1) karkooti (Nile mud); (2) taffel (some form of calcium carbonate).

The symptoms are usually emaciation and anæmia, with pain in the epigastrium, and a sensation of hunger, while constipation is common. Earth-eaters frequently suffer from agchylostomiasis.

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CHAPTER XLIII

DISEASES OF THE ALIMENTARY CANAL (*continued*)—SPRUE AND HILL DIARRHŒA

Sprue—Hill diarrhœa.

SPRUE.

Synonyms.—Ceylon Sore Mouth, Aphthoides Chronica, Tropical Aphthæ, Impetigo Primarum Viarum, Diarrhœa Alba, Psilosis Linguæ et Mucosæ Intestini, Endemic Diarrhœa.

The term 'sprue' is a phrase used in Holland and Scotland for aphthous stomatitis in children, and was applied to this disease by Manson and Van der Burg, the latter calling the disease in Batavia 'Indische spruw.'

Definition.—Sprue is a chronic catarrhal inflammation of the alimentary canal, of unknown cause, characterized by a peculiar ulcerative condition of the tongue and mouth, and by the passage of large, pale, frothy motions, the symptoms waxing and waning periodically.

History.—Hillary, of Barbadoes, in 1766, in a most remarkably able manner, describes the disease for the first time under the name 'aphthoides chronica.' His account is well worth reading, and there can be no possible doubt that his description refers to the disease we now call sprue. The Indian physicians Twining (1835), Grant (1854), Cunningham (1877), mention symptoms indicating that they were acquainted with a disease of this nature.

At the same time—*i.e.*, 1864 to 1883—French physicians noted a peculiar form of diarrhœa, commonly met with in Cochin China, which perplexed them considerably, a large number believing that it was dysenteric in nature, while others considered that it was probably a new disease.

In 1880 Manson was the first after Hillary to clearly define the disease, which he called sprue; and in the same year, and independently, Van der Burg described it under the term 'Indische spruw' in Batavia. In the next year (1881) Sir Joseph Fayrer delivered the Lettsomian Lectures on chronic white tropical diarrhœa. These three authors permanently established the disease as a clinical entity. Since then many important papers and articles have appeared, notably Roux's 'Traité' in 1888, and Thin's 'Psilosis' in 1897. The most modern account with a full history is Brown's monograph (1908).

Climatology.—The endemic home of sprue appears to be Asia, especially Malaya, Sumatra, Java, Siam, and Annam; but it also extends into Burma, India and Ceylon, China, Australia (East and South), New Caledonia, the Fiji Islands, and Japan. Possibly it exists in the West Indies, where Hillary originally described it, and it may occur all through the tropics; but if so, it must be rare in certain regions—as, for example, West Africa.

Ætiology.—The cause of sprue is quite unknown, though there are many theories. Thus Thin and Macfadyen found at times a special form of bacillus in the fæces, and noted the comparative absence of *Bacillus coli communis*; but no organism has as yet been shown to have a definite causative action. *Strongyloides stercoralis* has been noted in the motions, but is not the cause of the disease. Dysentery is not causative; at the most it can only be a predisposing cause of certain cases.

According to some observers, the disease is caused by bacilli of the *coli* group which only come into action after attacks of dysentery. According to others, the malady is due to some species of saccharomyces. Bassett Smith believes the disease to be a cirrhosis of the mucosæ, due to the action of bacteria. Van der Scheer's theory that the disease is a sequel of appendicitis is in our opinion untenable.

Pathology.—With an unknown causation, it is not easy to write an account of the pathology. It would appear as though the primary lesions are beneath the epithelium in both the tongue and the intestine, and cause the superficial desquamation and catarrh. In the intestine the disease begins with submucous congestion, after which follows thrombosis of the vessels, and exudation of hæmoglobin, and a round-celled infiltration. The mucosa suffers because its blood-supply is damaged, and therefore necrosis takes place, the glands and villi being affected. The œsophagus and stomach also suffer. The liver is at first enlarged and congested, but later becomes atrophied and small. The fact that the tongue, œsophagus, stomach, and intestines are affected would indicate that something deleterious is being carried by the blood-stream to these organs, rather than that something is acting from the surface. The irritation of the liver may be due to the same cause.

When once the mucosæ are damaged, the chemical processes of digestion and the absorption of their products must be interfered with, while at the same time the absorption of poisons from the alimentary canal must be easier. Indeed, there is evidence of this in the increase of indigo blue in the urine, which is at times marked.

These two conditions would lead to an atrophy of the liver, which organ is one of the great safeguards against a toxæmia of intestinal origin. When the liver is sufficiently damaged, a toxæmia is possible, and occurs ; hence, possibly, the advantage of the treatment by liver-soup or other preparations of liver.

The damaged condition of the mucosa of the mouth and tongue makes mastication difficult. The denuded condition of the œsophagus causes the burning pain during swallowing ; the condition of gastric and intestinal mucosæ causes the dyspepsia and diarrhœa of the disease. The diarrhœa is characterized by pale, frothy motions, the explanation of which is as follows :

On opening the bowels post mortem, the observer is struck by the fact that, though there may be plenty of bile in the duodenum and in the higher portions of the bowel, this gradually disappears until, in the lower parts of the small intestine, the contents appear white. In normal fæces bilirubin should be changed into stercobilin (hydrobilirubin), which is urobilin, and is identical with that found in the urine.

Vaughan Harley has shown that in the upper third of the small intestine the normal fæces are of a yellowish colour, due to bilirubin. In the middle third they are of a whitish or greyish colour, probably owing to the bile-pigments being converted into chromogens, which become green in the lower third. After passing the ileo-cæcal valve, the bile-pigments are converted into urobilin by the action of putrefactive bacteria, but a considerable quantity of this is in the form of a chromogen. If the pancreatic juice is absent, a colourless form of urobilin is found, called leuco-urobilin, which, on oxidation by air, may be reconverted into urobilin. It would appear, therefore, that the intestinal flora has altered its character in sprue, probably owing to some abnormality in the pancreas or the bowel.

Morbid Anatomy.—The body is emaciated, and the skin often hangs loosely, and there may be œdema about the ankles. The tongue shows small areas of infiltration into the connective tissue, vesicles, and small ulcers. The filiform papillæ atrophy, and the fungiform papillæ become swollen and prominent. The pillars of the fauces and the tonsils may show subepithelial inflammation, and even suppuration and ulceration. The œsophagus is inflamed, and its mucosa is attenuated in places. The mucosa of the stomach may be pale and atrophied, or rough and cirrhotic. The mucosa of the small intestine may be slightly eroded, or may be so destroyed that the whole bowel is diaphanous with vascular arborizations ; or there may be effusion into the solitary and agminated glands. The contents are bile-stained in the upper parts, and whitish lower down. The large bowel may be ulcerated. The liver is atrophied, but otherwise normal. The pancreas may be normal, inflamed, or cirrhotic. The peritoneum may be thickened and chronically inflamed, and in some cases show adhesions. The other organs are normal as a rule, but sometimes they are atrophied.

Symptomatology.—The incubation period of sprue is quite unknown, and the onset is insidious, without marked symptoms, which are usually merely failing strength and an undefined sense of illness. The disease may begin with diarrhœa and intestinal symptoms, or with mouth symptoms only.

Usually it begins with slight attacks of sore mouth, indigestion, and morning diarrhœa, often of a bilious nature ; but as none of these are severe, and all are evanescent, the patient thinks little or nothing about them, and does not consult a medical man until the disease is well established. Three symptoms now worry the patient—viz., sore mouth, indigestion, and morning diarrhœa.

On examining the mouth, the dorsum of the tongue will be seen to have a whitish fur, through which the swollen fungiform papillæ are projecting. The sides and tip of the tongue are red and inflamed, with often small vesicles, small ulcers, and bare patches, which are very tender. Similar patches may be noted under the tongue near the frenum, on the inside of the cheeks, on the palate, and on the pillars of the fauces. A little ulcer, called Crombie's molar ulcer, may be seen near the two last upper or lower molar teeth. So tender is the mouth at times that deglutition, mastication, warm or spiced foods, acid or alcoholic liquors, cause much pain. In addition, mucus may be noticed clinging to the pillars of the fauces and to the back of the pharynx. This mucus is a source of great distress to the patient, as it accumulates in considerable quantities, especially if some warm fluid has been taken, and the effort to get rid of it makes him almost sick. On swallowing food, a burning pain is felt along the course of the œsophagus and over the sternum, as though there was something raw inside (as, indeed, there is). The voice is said by Thin to be altered at times, but we have not specially noted this.

The neck, thorax, and arms may show signs of emaciation. The abdomen is swollen, sometimes markedly so, especially in the epigastric region, and the wall is soft and relaxed. The patient complains of dyspeptic symptoms—viz., a sensation of discomfort and distension after meals, with acid eructations, and sometimes vomiting. Early in the morning he feels symptoms of intestinal discomfort, and passes a few copious, greyish, offensive, frothy motions, and no more for the rest of the day. After these motions he may feel much better, and have a good appetite.

Examination of the fæces shows mucus, epithelial débris, and many bacteria, and in some cases eggs of various worms may be present. The quantity of fæces passed varies with each motion, but is in excess of the normal, this being due to solids rather than liquids. The excretion of nitrogen and fat is increased.

The most complete analysis of urine and fæces has been carried out by V. Harley and Goodbody. The patient, weighing 36·87 kilogrammes, was on a milk diet, containing 12·99 grammes of nitrogen, 76·44 grammes of fat, 82·32 grammes of carbohydrates, and 1,960 c.c. of fluid. The urine passed measured 1,050 c.c. ; specific gravity 1,012 ; urea, 16·8 grammes ; uric acid, 0·8 gramme ; ammonia, 0·44 gramme ; phosphates, 1·27 grammes ; chlorides, 3·89 grammes. Total sulphates, 1·47 grammes, of which 1·35 grammes were alkaline and 0·12 aromatic. The average daily quantity of the motions was 255 grammes, of which 79·46 were water, 1·47 nitrogen, 35·92 fat. The nitrogen given in the food was 12·99 grammes, and that in the fæces 1·47 grammes ; therefore 88·68 per cent. had been absorbed. The fat in the food was 76·44 grammes, and that in the fæces 35·92 grammes ; therefore 53·01 per cent. had been absorbed. The colour of the fæces was greyish-green to greyish-white, but gave a distinct urobilin reaction, due to the leuco-urobilin. Schmidt's test for urobilin is performed by adding a concentrated solution of perchloride of mercury to the fæces, when a bright red colour is developed if urobilin is present. If there is much urobilin, the colour appears within five minutes ; if little, in five to fifteen minutes ; if very little, in half an hour. The colour deepens for twenty-four hours. More analyses on the above lines are required. With regard to the stomach, at times there is said to be complete achlorhydria (Manson).

The blood coagulates slowly, and there is always some reduction of the red cells, which may fall as low as 3,000,000 to 1,000,000 per cubic millimetre. The colour-index is low, and the structure of the cells is normal. The white cells are also reduced to about 6,000 to 2,800 per cubic millimetre. The ratio of white to red is about 1 to 400 in bad cases. A differential count shows an increase in the mononuclears and eosinophiles.

The urine requires more investigation, but as far as evidence goes at present it is not abnormal, showing only an increase in indigo blue and urobilin, and at times Cammidge's reaction for pancreatitis.

The buccal, intestinal, and other symptoms may markedly improve, even without treatment, but only to get worse again ; and this is repeated time after time.

In due course the patient becomes very emaciated, weak physically, and depressed and irritable mentally. The skin becomes harsh ; the mucosæ anæmic ; the tongue becomes smooth, glazed, reddish-yellow, and small, and is often furrowed by cracks ; indigestion is marked ; and the diarrhœa is worse. The patient continues to lose weight, and emaciates rapidly, the skin hanging in loose folds, the abdomen blown out with gas, the liver small and atrophied, the ankles œdematous, while the pulse becomes slow and feeble.

After this has gone on for a long time, the emaciated, worn-out, irritable person dies of an acute attack of diarrhœa or cardiac failure. Sprue is essentially a chronic disease, with remissions, intermissions, and recurrences, but, unless taken seriously in hand, goes steadily from bad to worse.

Some writers distinguish three stages—a first stage, with oral and dyspeptic symptoms ; a second stage, with marked intestinal symptoms ; and a third stage, with toxæmia, emaciation, and anæmia ; while cases are sometimes seen which are atypical—that is to say, where there are the mouth symptoms without the intestinal symptoms, and *vice versa*.

Complications.—The complications met with in the course of the disease are : Acute diarrhœa ; dysenteric diarrhœa ; hæmorrhage ; meteorism ; pancreatitis ; myalgia ; insomnia ; helminthiasis, especially agchylostomiasis ; impacted fæces ; chronic appendicitis ; jaundice ; diabetes ; and pernicious anæmia.

Diagnosis.—The diagnosis of the disease is to be based upon the irregular chronic diarrhœa occurring especially in the morning, and associated with flatulent dyspepsia, causing distension of the abdomen, and the passage of fermenting, abundant, clay-coloured motions. With these symptoms there will be progressive emaciation and anæmia, and when to these the characteristic mouth-lesions occurring in a person living in the tropics are added, it is indeed difficult to imagine any disease with which it could possibly be confounded. Van der Scheer considers that the discovery of fat in the motions is a diagnostic sign before the disease begins; but this condition may also be found in pancreatitis. Low says that the so-called psilosis pigmentosa of Barbadoes is pellagra. The diseases from which sprue should be distinguished are stomatitis, hill diarrhœa, chronic dysentery, and chronic pancreatitis.

Stomatitis.—All forms of stomatitis are very common in the tropics, and may be accompanied by intestinal symptoms such as diarrhœa. The stools, however, do not show the peculiar characteristics of sprue—viz., the white colour, the frothy appearance, and the copious amount passed in the twenty-four hours.

Thrush.—This is easily diagnosed by examination of the white patches, in which *Endomyces albicans* will be found. It is, however, to be noted that in long-standing cases of sprue, as in all chronic complaints, thrush may develop.

Hill Diarrhœa.—The patient generally gives a history of residence at a high elevation, and the diarrhœa is as a rule present only in the morning, while mouth symptoms are absent. We have, however, seen several patients in whom sprue has developed after repeated attacks of what to all appearance was simply hill diarrhœa.

Chronic Dysentery.—In chronic dysentery there is an absence of the mouth symptoms, while the motions are not whitish in colour, and may contain blood and mucus during the exacerbations. The diarrhœa of dysentery is generally accompanied by griping, while that of sprue is not. In chronic dysentery pain is often felt on pressure over the sigmoid and descending colons. In some cases microscopical and bacteriological examination of the stools for entamœbæ and the Shiga-Kruse bacillus may be necessary to clear the diagnosis.

Though personally we consider sprue and chronic dysentery to be different diseases, still we have seen several cases of sprue developing in old-standing cases of chronic dysentery.

Chronic Pancreatitis.—Absence of the mouth symptoms of sprue and presence of tenderness in the region of the epigastrium and the passage of large quantities of fat in the motions, together with Cammidge's crystals in the urine, will enable the diagnosis of chronic pancreatitis to be made.

Prognosis.—The prognosis in any case of sprue is serious, because, unless the patient will honestly co-operate with the doctor, he will go from bad to worse. We are of the opinion that, no matter how mild the case may be, the patient should be warned of the danger.

If treatment is properly carried out, the prognosis improves considerably, but even then relapses are apt to occur.

Treatment.—The causation of the disease being unknown, the treatment must be symptomatic.

An attempt must be made to soothe the alimentary canal, and to give it as little work to do as possible, so that it may repair itself. This line of treatment will necessitate rest in bed and a careful diet, after the bowels have been swept as clear as possible of decomposing material.

While this is proceeding, care must be taken to avoid chills, as they aggravate the disease. Lastly, an attempt should be made to treat those symptoms which worry and annoy the patient.

The treatment, therefore, may be classified into—

1. The Co-operation of the Patient.
2. Rest in Bed.
3. Suitable Clothing.
4. Removal of Fermenting Bowel Contents.
5. Diet.
6. Medical Treatment.
7. Change of Climate.

1. THE CO-OPERATION OF THE PATIENT.—The nature of the complaint and the dangers which the patient runs must be carefully explained to him, and the line of treatment sketched out. Further, he must be told that its success or failure largely lies in his own hands. If he has not the strength of will to persevere, even when at first success seems far from certain, he might as well not begin. If he agrees to co-operate, then he must be carefully weighed, and a chart kept of his weights.

2. REST IN BED.—The second point is that the patient must remain in bed for a little time, and use the bed-pan and the urine-bottle, in order to give the bowels as much rest as possible, and warm water must be used in sponging.

3. SUITABLE CLOTHING.—The underclothes and pyjamas should be of wool or flannel, in order to avoid chills.

4. REMOVAL OF FERMENTING BOWEL CONTENTS.—The treatment should begin with a dose of castor oil, to remove the fermenting contents of the bowels.

5. DIET.—The various diets advised may be arranged as follows:

(*a*) The Milk Diet.
(*b*) The Milk and Fruit Diet.
(*c*) The Fruit Diet.
(*d*) The Meat Diet.
(*e*) The Meat and Milk Diet.

(*a*) *Milk Diet.*—The real basis of the treatment of sprue at present is the milk diet.

In the tropics, this milk should be obtained from a cow kept for the purpose, or from some really reliable dairy, as the danger of contamination is great. Even when the cow belongs to the patient, great care has to be taken that the milk is not adulterated by the household servants. We can never forget that once the milk of a peculiarly careful household, collected, apparently, under strict precautions, was found on analysis to be grossly adulterated. The lesson we have drawn from the above is to get a sample analyzed from time to time. This analysis costs but little, and the possibility of its being carried out at any time puts a certain amount of restraint upon would-be adulterators.

There is a considerable difference between the average composition of the milk supplied by *Bos taurus*, the straight-backed cow, and *B. indicus*, the hump-backed cow, which, in general terms, may be summarized by saying that the milk of the latter is much richer than that of the former. We have investigated this point, and are of the opinion that if 3 per cent. of fat is considered to be an average for *B. taurus*, then 5 per cent. should be reckoned for *B. indicus*.

In placing a patient upon a milk diet, the composition of the milk should be carefully considered, especially as regards the fat, for, as Harley and Goodbody have shown, no less than 47 per cent. of the milk-fat is passed out in the fæces.

Milk with high percentages of fat should, therefore, be diluted with whey, when the amount of nitrogen will be kept up, while the percentage of fat is diminished. Whey is easily made in the tropics by means of the juice of limes.

Preferably the milk should not be boiled or sterilized, but boiling, apparently, does not interfere with its beneficial properties, and therefore, if desired, or thought necessary—*i.e.*, owing to the risk of typhoid—there is no harm in so doing. In cold weather it should be warmed before being taken. It can be aerated in a seltzogene if desired, and can be mixed with Vichy water. Finally, it must be remembered that milk is not a perfect food for an adult, however suitable it may be for a child.

It is as well to begin with a small quantity, and to gradually increase the amount. Every medical man sooner or later adopts his own method of carrying this out, and we will, therefore, only give general directions. If the case is very severe, with vomiting and much diarrhœa, it is as well to begin with whey only, which the patient should sip slowly, and practically *ad libitum*—*i.e.*, about 7 to 8 pints per diem. As soon as the urgent symptoms are relieved, milk must be added to the diet, as whey alone is starvation.

If the case is of moderate severity, milk can be begun at once, 3 pints per diem being given in the more severe, and 4 pints in the less severe, cases—*i.e.*, 60 to 80 ounces—which should be divided into not less than ten meals at regular intervals during the day. The milk must be slowly sipped or taken through a glass tube, which, of course, should be carefully boiled after each meal. On no account must the patient be allowed to drink the milk in gulps. It is, perhaps, as well to define a limit of time—say about twenty minutes—as the minimum time for a meal.

If the symptoms improve, it is necessary to increase the milk gradually every few days until 6 to 7 pints—*i.e.*, 120 to 140 ounces—are given; but in doing this, it is better to increase the number of meals rather than the quantity at a given meal. Twelve meals in the twenty-four hours are not difficult to arrange.

If the symptoms do not improve, the milk must be reduced gradually, or whey must be tried ; but as soon as the urgent symptoms of diarrhœa and vomiting abate, the milk must be gradually increased, and, indeed, the starvation must not be long continued in any case. Starvation diets are dangerous in severe cases when the patients are emaciated and weak ; and hence, while they are being employed, great care is required in nursing.

If the milk is succeeding, the diarrhœa ceases, the mouth troubles diminish, and the patient feels better. The fæces will at first be pale and grey, but, as improvement continues, stercobilin will appear, as evinced by the brown colour. This change in the colour of the fæces is a most important and excellent sign.

But even if milk is agreeing with the patient, there will be much trouble, as there is often strong objection to milk only. Another difficulty is constipation, and this must be relieved by enemata. Sometimes the milk does not agree, causing vomiting and pain. Usually this can be relieved by alkalinizing the milk with bicarbonate, 1 grain to the ounce, or the citrate of soda, 2 grains to the ounce of milk (convenient tabloids are prepared by Burroughs Wellcome and Co., of this salt), or by adding Apollinaris or Ems water in the proportion of equal parts, or lime-water, 1 to 6 of milk. As soon as a definite improvement appears, and the weight begins to increase, the patient should be allowed to sit up, but great care must be taken to avoid chills. Milk diet should be persisted in for a month or six weeks, but may be modified by the addition of fruit—*e.g.*, strawberries, bananas, or apples—as will be described later.

Then eggs may be beaten up in the milk ; chicken-broth can be tried ; then Benger's food, or some other simple food—Allen and Hanbury's, Mellin's, Albany food, Carnrick's soluble food, Sanatogen, or Plasmon. Then fish, chicken, or sweetbreads, with a biscuit, and, later, potatoes ; and finally, the patient is put on to a diet of eggs, toast, dilute China tea, soups, white meats, custard-puddings, milk. But he must avoid dark meats, most vegetables, spiced foods, iced drinks, and all indigestible substances. Alcoholic drinks in every form are bad, both during the illness and afterwards. Nor is smoking to be encouraged ; we, personally, are much against it.

But, unfortunately, a case of sprue is not so easy to treat as indicated above, for, while the food is being gradually and carefully increased, relapses are not infrequent, and a return to milk may be necessitated. The patient gets weary, and at times exceedingly angry about this dieting, and, indeed, is apt surreptitiously to kick over the traces, with disastrous results. The prohibition of alcohol also leads to trouble, but our experience about this is quite clear : if alcohol is taken, the progress of the patient is seriously hindered.

Before leaving the milk diet, two points ought to be mentioned, concerning one of which we have had considerable experience ; concerning the other, none at all. First of all, there can be no reasonable doubt as to the advantages of liver-soup—*i.e.*, soup prepared from calves' or sheep's livers—in the milder cases of sprue, or in the return to ordinary food of a severe case. The liver treatment is really an old native remedy in Ceylon. We do not profess to advance views as to its action, but in a certain class of cases it is of benefit. Secondly, gall-pills and pancreatic preparations have been advocated by some; but of these we have no experience.

(*b*) *Milk and Fruit Diet.*—A milk and fruit diet has been found to be even better than a pure milk diet in many cases. The milk is administered as already described, but, in addition, fruit is given. Strawberries are most highly recommended, beginning with ¾ pound and gradually increasing to 2½ pounds per diem. They should be crushed, and eaten with sugar and cream. In lieu of strawberries bananas (not plantains, though people often call bananas plantains, the difference being that a banana shows three cells on transverse section and a plantain five), pears, grapes, in the same weight as the strawberries or apples, from ½ pound to 1½ pounds per diem. If these cannot be obtained, the juice of oranges, papaya (1½ pounds per diem), avocado pears, mangosteens, and sapodilla, may be used.

Fresh Bael fruit is excellent, but must be carefully prepared. It may be boiled in water and then cut open and shredded by means of a fork into warm milk, in which it is pounded with castor-sugar, and finally strained through a fine strainer to remove all débris. This should be used three times a day. Preserved fruit is said to be useful, if fresh fruit cannot be obtained. Acid fruits, such as pineapples and sour-sops, should be avoided, and, personally, we do not advise the use of mangoes.

(*c*) *Fruit Diet.*—This was first advocated by Van der Burg, and usually consists of grapes and pears; but it appears as though almost any fruit which is not acid might be used.

(*d*) *Meat Diet.*—If the milk or fruit diets fail, it is advisable to try a meat diet, or this may be made the basis of treatment from the beginning. Cantlie is the great supporter of this dietary.

If the patient is very ill, it may be necessary to begin with raw-meat juice, prepared by pounding sufficient good raw flesh in a mortar, so that, with the addition of 2 ounces of water and 20 minims of dilute hydrochloric acid, 6 ounces of meat-juice is obtained on straining. The quantity of meat required to obtain these 6 ounces will sometimes be quite considerable, and, as it varies in different regions, must be obtained by preliminary experiment. A little salt should be added to this juice, and 1 teaspoonful should be given every quarter of an hour in very bad cases, and rapidly increased in amount if successful.

As soon as the very serious symptoms subside, the meat diet should be started. Brown gives the following directions for preparing a meat diet: Take 2 pounds of good raw meat, free from fibrous matter, fat, and gristle, and 2 ounces of fresh suet, and mince and pound them up thoroughly. Sprinkle the pounded mass with a little salt, and divide into six portions. One portion, cooked in a small, well-buttered saucepan until the red colour has just disappeared, is given six times a day, as convenient. This portion, when cooked, is estimated as weighing 4 ounces. In addition, ½ pint of plain warm water, rice or toast water, is sipped half an hour before a meat meal, and a little tea, with lemon-juice instead of milk, taken twice daily. It may, perhaps, be as well to remind the reader that rice-water is an infusion of roasted rice, In about a week this meat diet should be changed to a modified meat diet, which is first produced by the addition of fruit, followed in a little time by chicken, then and gradually by eggs, biscuits, and fish, until the dietary already mentioned under Milk is reached.

With a modified meat diet some people combine curdled milk. This is based upon Metchnikoff's researches, which showed that if the *Bacillus acidi lactici* is taken with milk, it generates large quantities of lactic acid in the intestines, particularly in the large bowel, and that this acid interferes with intestinal toxins. Various preparations of the germ have been placed on the market, including ' Sauerin,' made by Messrs. Allen and Hanbury, and said to be a pure culture of the germ. Brown gives the following directions for its use: 2 pints of milk are heated to 160° F., to kill off any bacteria which might happen to be present, and then are allowed to cool in a jug which has been boiled. When 100° F. is reached, 6 tablets of Sauerin are added, and 2 tablespoonfuls of sugar, when the milk is curdled in about three hours. This curdled milk is taken four times a day, between the meals of a modified meat diet, and is said to be efficacious.

It may be mentioned that curdled buffalo-milk is commonly used by the natives of Ceylon as a part of their food, and curdled milk is also used in India, and, indeed, in many other places by natives.

Under the heading of Meat Diets must be placed Cantlie's treatment, which consists of putting the patient to bed, applying a hot wet pack from the nipples to the groin for two hours, morning and evening, and giving three meals of 5 ounces of meat per diem, and, in addition, either beef-tea, beef-jelly, calves'-foot jelly, or a plain jelly every two hours. Castor oil is administered in 1½-drachm doses every morning for the first three days, and santonin in 3-grain doses morning and evening for three days. Strawberries, to the quantity of 3 to 4 pounds per diem, are also allowed between meals. When the stools become solid, and show brown colouring matter, a poached egg and pounded chicken are added, and, later, minced chicken, and, still later, the undercut of meat, with stewed celery, seakale, vegetable-marrow, pulled bread, and thin slices of bread, baked in an oven for twenty minutes.

(*e*) *Meat and Milk Diet.*—Cantlie now advocates that when a patient is on a meat diet, this should be stopped every third or fourth day for twenty-four hours, and that milk only be given during this period.

6. MEDICAL TREATMENT.—It may be said at once that astringents as a rule are dangerous, and that antiseptics are not useful. Santonin, which must be yellow, has been strongly recommended by Begg, who gives 5 grains night and morning in salad oil; but we have seen no benefit by this treatment. Recently Cantlie has had good results by the administration of 20 grains of ipecacuanha daily for two or three days in advanced cases.

The mouth may be treated with any appropriate mouth-wash—*e.g.*, glyco-thymoline, glycerine and borax, diluted liquor aluminis, etc. The teeth require attention, and if there is any pyorrhœa, this should at once be treated by syringing or spraying between the teeth with peroxide of hydrogen solution. Pain may be relieved by painting the raw surfaces with 2 to 5 per cent. solution of cocaine, novocain, alypin, or stovain. The pain along the œsophagus requires morphia. Janowski recommends 5 to 10 drops of a solution of 1 in 1,000 adrenalin, which, he says, gives prompt and permanent relief for œsophagitis. The muscular pains may be relieved by massage, or by pilocarpine nitrate, given in $\frac{1}{10}$ to $\frac{1}{5}$ grain doses three times a day. Intestinal pain may be relieved by hot packs, as recommended by Cantlie. Acute diarrhœa must be checked by a dose of liquor opii sedativus or lead and opium pills. Dysenteric symptoms must be treated as described under Dysentery.

CHANGE OF CLIMATE.—It is obvious that, if possible, the patient should be transferred from the tropics to the temperate zone, but only if he is strong enough to travel. But there is no advantage in putting him on board a ship in such a condition that he will probably die when changing from the warm to cooler weather. Personally, we are not in favour of a person being sent from the low country to the hills. If he is able to travel, let him go to the temperate zone.

Prophylaxis.—Nothing of any practical value can be said under this heading.

HILL DIARRHŒA.

Definition.—Hill diarrhœa is a gastro-intestinal catarrh of unknown cause, occurring mostly at high altitudes in tropical regions, and characterized by the passage of several liquid, frothy, light-coloured motions in the early morning.

History.—Hill diarrhœa was first described by Grant in 1854, in the same paper as that in which he dealt with sprue and dysentery, and later as a disease quite distinct from sprue by Crombie in 1892. The latter writer held that it was liable to occur at an elevation of 6,000 or more feet in India, Europe, and elsewhere. In India he believed the monsoon to be a potent factor, associated, probably, with a diminished barometric pressure. We have seen cases in Ceylon occurring at much less elevation—for example, at about 3,000 to 4,000 feet.

More recently Duncan has put forward the view that mica in the water is the causative agent. This mica is found in the laterite —*i.e.*, weathered gneiss—which is a common geological formation in the tropics. Singer considers that he has met this disease in four out of six Europeans on an expedition to Abyssinia, when they reached a height of about 5,000 feet.

Ætiology.—The causation of the disease is quite unknown. The theories are: diminished atmospheric pressure, the irritation of mica, fæcal contamination of the water, and exposure to cold.

Pathology.—Very little can be said under this heading, except to invite attention to what has already been written under the heading of Sprue with regard to the formation of leuco-urobilin, and to point out that it is obviously to the formation of this body, and not to anything wrong with the liver, that the colour of the motion is due. The morbid anatomy would appear to be totally different from that of sprue, and to be a congestion of the mucosæ of the stomach and bowels, with a proliferation of the mucosal lymph and fibrous tissue in chronic cases. On the surface of the mucous membrane of the small and large bowels there is a thick layer of mucus, but no ulceration.

Symptomatology.—The disease generally begins soon after the patient has arrived in the hills from the plains.

have already said, the principal endemic centre is Lower Bengal, whence it can spread through India, and, indeed, over the greater part of the world, by human agency and along lines of human intercommunication, but in so doing it may miss places on the direct route of its march. The reason of this is not clear. Certainly climatic conditions may be of importance, and perhaps a low level of the subsoil water and a high earth temperature, together with an imperfect sewage disposal and a contaminated source of the drinking-water of the place, may have something to do with this anomaly.

Another point which is by no means understood is the fact that the disease remains for years in the endemic region, and then suddenly spreads in epidemic and pandemic form, extending at times over the whole world.

The ætiology may, therefore, be summarized by saying that the disease is caused by Koch's *Vibrio choleræ* acting in the presence of some unknown bodily condition or conditions, and spread directly from man to man by fomites, water, insects, and food, but the reasons for its endemicity and epidemicity are unknown.

When travelling from one place to another, it always adopts channels of human intercommunication, which may be ships, rivers, roads, or railways. When introduced into a locality, it will give rise to a widespread epidemic if the sanitation is so defective that the germs gain access to the drinking-water, but will be far less extensively spread if due to food or insects, and will be merely sporadic if spread from man to man.

Pathology.—The vibrio grows in the lumen, the glands, the epithelial cells, and the mucosa of the small intestine, probably producing an endocellular toxin, which is set free and causes the symptoms.

The question of toxin formation has, however, been much debated. Thus, in 1905, Brau and Denier considered that they had obtained a soluble toxin. In 1906 Kraus said that he had obtained a soluble toxin which caused the disease, and in the same year MacFadyen obtained a virulent endotoxin. In 1907 Strong carefully investigated the subject, and concluded that he was unable to find a soluble toxin as described above, but that MacFadyen's endotoxin was the true toxin which caused the symptoms in man. This endotoxin causes great gastro-intestinal disturbance, leading to the passage of fluid from the blood to the bowel in the following order: First water, and then inorganic salts, especially sodium chloride; later, phosphates and potassium salts; and still later organic substances. This endosmosis causes a great concentration of the blood, producing a high specific gravity, which may reach 1073 to 1078, which is associated with a great increase in the erythrocytes—8,000,000 per cubic millimetre, according to Rogers and Megaw—with a corresponding increase of the hæmoglobin and of the leucocytes, which may number from 14,000 to 60,000 per cubic millimetre. At the same time the alkalinity of the blood is decreased and its coagulative power altered, while the oxygen contained therein is decreased.

The concentration of the blood causes a fall in the blood-pressure, which is indicated by the feeble compressible pulse, but which, to be studied properly, requires investigation by means of a Riva-Rocci's instrument, as has been done by Rogers and Megaw, who found that in typical collapse the blood-pressure might be only 60 to 50 millimetres of mercury, when the patient is markedly cyanosed and restless. If the case is not so serious, the pressure may be higher—70 to 80 millimetres of mercury—and if the patient is on the road to recovery it may reach to 90 millimetres. As a result of this low blood-pressure, the urine may be suppressed or scanty, with a high specific gravity, albumin, casts, and a large quantity of indican.

The body appears to react to the disease by the pouring out of substances from the blood which are probably bactericidal, though Edwards's attempt to prove this failed because of decomposition and the admixture of other micro-organisms.

When recovery is about to take place, the specific gravity of the blood decreases, the blood-pressure rises, and the urine becomes abundant. As convalescence continues, the great danger is secondary infection of the body by other micro-organisms, which may cause serious illness and even death.

Morbid Anatomy.—Usually post-mortem rigidity is very well marked, and the body keeps warm for some time after death. On cutting into the tissues, it is noticed that they are very dry, and that the blood is often thick and tarry. On opening the peritoneal cavity, the hand experiences a peculiar sticky sensation not felt in any other disease with which we are acquainted.

The stomach is usually empty, and the bowels are reddish in appearance, with injected vessels. When a piece of small bowel is opened, the contents are usually found to be whitish or greyish grumous material; more rarely will the contents be blood-stained. These contents consist of food particles, epithelial cells, red and white corpuscles, and micro-organisms. When allowed to stand, they separate into liquid and solid portions, the former containing albumin, and having a specific gravity varying from 1005 to 1015. The mucosa of the stomach and bowels is hyperæmic and swollen, and may be marked by ecchymoses. There is usually some enlargement of the solitary and agminated glands, as well as of the mesenteric glands.

The liver is generally congested, and the ducts full of bile; the spleen is shrunken; the kidneys are swollen, and often ecchymotic, with tubules blocked with granular débris and cells in a state of cloudy swelling. The right heart is often dilated, and the whole venous system full of blood, while the arterial system and the left heart is empty. The lungs are collapsed, dry, and anæmic, and the brain may be congested.

Microscopically, the vibrios may be seen in Lieberkühn's follicles.

in the epithelial cells, and in the mucosa of the intestine and the stomach. The kidney shows vascular congestion and destruction of the epithelium. Usually the vibrios do not penetrate into the blood-stream, and therefore the disease is mainly a general intoxication; but Rebowski records cases in which they have been found in the liver, the kidney, and the heart, thus producing a general infection.

If the post-mortem is held on a case which has died during the state of reaction, pneumonia and the signs of other secondary infections may be found.

Symptomatology.—A typical case of cholera has an incubation period which varies from a few hours to a few days (three to six). The onset is usually sudden, but there may be prodromata in the form of diarrhœa, or merely a feeling of illness and malaise. The attack begins with diarrhœa, with or without colicky pains in the abdomen. The motions are at first fæculent, and contain bile, but soon assume the typical rice-water appearance, in which they are fluid and acholic, containing numerous white flakes, which, when examined, are found to be composed of mucus containing vibrios and epithelial cells, while exceptionally the motions contain blood. Vomiting generally appears early, food being first expelled, followed later by a watery fluid, with which bile and occasionally blood may be mixed. The patient complains of thirst, and at times of hiccough. As the purging and vomiting proceed the urine diminishes, and may stop, and fluid departs from the subcutaneous tissues, which therefore contract, so that the facies alter, the nose becoming sharp, the cheek-bones prominent, the eyes sunken, and the skin of the fingers becomes wrinkled like that of a washerwoman. Whilst this is taking place, the circulation becomes profoundly affected, the blood-pressure falls, the pulse becomes weak and rapid, the heart-sounds diminish, and the lips, face, and nails become bluish. The patient now has difficulty with his breathing, and his voice becomes weak and husky. Painful cramps appear in various muscles, but especially in the calf, arm, and abdominal muscles, while the reflexes are diminished. The mind is quite clear, but the patient is apathetic, except when agonized by the cramps. The skin feels cold, and the axillary temperature falls below normal, but that of the rectum may be considerably raised. If no change for the better takes place, the patient passes into the algide stage, in which the failure of the circulation becomes more marked, the pulse almost disappearing at the wrist, the heart becoming weak and irregular, the respirations laboured, the skin cold and deeply cyanosed, the urine suppressed, while the diarrhœa may or may not cease, and the temperature falls far below normal. The first heart-sound becomes impure, or a hæmic systolic murmur may be present, and the second may be faint, and friction-sounds may be heard over both the pericardium and pleura. The patient may now become comatose, and death supervenes in from twelve to thirty-six hours after the onset of the attack. If recovery is to take place, the diarrhœa diminishes, the skin becomes warmer, the pulse and blood-pressure improve, and after a time bile appears in the motions, and the skin fills out with fluid again.

Sometimes convalescence is rapid. In some a secondary febrile condition ensues, which may last for several days, or even for a couple of weeks.

The patient may at times pass into a *status typhosus*, with flushed face, raised temperature, dry brown tongue, low muttering delirium, with subsultus and toxic tremblings, and toxic rashes, which may be erythematous, papular, or hæmorrhagic. The urine is diminished in quantity, has a high specific gravity, and contains albumin and casts. The motions are somewhat like those of typhoid, or may be bloody.

Death may take place during this stage from complications, or recovery may ensue after a long convalescence. The infection of the convalescent may be said to have ceased when on three separate days the bacteriological examination of the motions is negative.

The typical course of the disease, as described above, is often arbitrarily subdivided into three stages: (1) The stage of evacuation; (2) the algide stage; and (3) the stage of reaction, when the patient is about to recover.

Varieties.—Cholera cases at times present many varied features, which are usually classified into—

1. *Ambulatory Cases.*—These are cases in which, without any signs of disease, the vibrio may be obtained from the fæces. These people are genuine carriers of the disease.

2. *Choleraic Diarrhœa.*—Choleraic diarrhœa is characterized by severe purgation, associated with the passage of yellowish motions, which contain the specific vibrio. This condition may be recovered from, or may pass into a typical attack of the disease.

3. *Cholerine.*—The patient is suddenly seized with abdominal pains, and passes numerous fæculent motions, followed by typical rice-water motions, which speedily cease, and the patient quickly recovers without further symptoms.

4. *Cholera Gravis.*—This is the typical form already described.

5. *Cholera Sicca.*—In this type the patient becomes rapidly collapsed, and dies before the typical symptoms of diarrhœa and vomiting can appear. The post-mortem and the bacteriological examination of the bowel contents reveal the true nature of the disorder.

Complications.—In rare cases hyperpyrexia has been noted during the attack, but usually all the complications occur during the stage of reaction, and are due to secondary infections. The most common are pneumonia, enteritis, and inflammation of the kidney. Pregnant women always abort, and the fœtus may show signs of the disease. The reason of this abortive tendency is, according to Schütz, because cholera has a powerful effect upon even the non-pregnant uterus, causing hæmorrhage during the stage characterized by muscular cramps.

Sequelæ.—After such a severe illness, it is usual to find more or less permanent damage to the health of the victim. Thus anæmia, inflammation of the parotid, gangrene, ulceration of the cornea, astigmatism, or other errors of refraction, a tendency to diarrhœa, and digestive disturbances, may persist for a long time.

Diagnosis.—The diagnosis is easy during an epidemic, but it may be very difficult in the period when there are only a few sporadic cases preceding the outbreak.

So closely may cholera be simulated by ptomaine poisoning as regards the collapse, and by infections with germs of the paratyphoid group, which we have seen produce typical rice-water motions, that it is perfectly useless in a sporadic case to attempt to make an accurate diagnosis without a bacteriological examination, and even this has to be performed with the greatest care, as there are many vibrios which are undistinguishable without special tests from the *Vibrio choleræ* Koch. We recommend the following method:

1. Make films from the rice-like flakes, and stain with diluted Ziel carbolic fuchsin (1 in 50) for ten minutes, or with Löffler's blue, five minutes. If a large number of curved rods be present, cholera may be suspected; but a definite diagnosis should never be based on the simple microscopical examination, as comma-like germs are found in many cases of ordinary diarrhœa, and even in normal stools.

2. Take a rice-like flake, and smear it direct on to the surface of Mackonkey's lactose-agar plate, using a sterile bent glass rod or Kruse's platinum pencil. Inoculate with the same rod or pencil without recharging the surface of two more plates, and incubate at 35° C. The colonies of the cholera and cholera-like vibrios develop on Mackonkey's medium as delicate small, yellowish, roundish dots within twelve to eighteen hours. Any suspicious yellowish colony should be examined, and the germ investigated as regards the following characters:

(*a*) *Motility.*—The cholera vibrio is very actively motile.

(*b*) *Morphology.*—The cholera organism is often bent, comma-like, but may be straight, bacillus-like.

(*c*) *Agglutination.*—A strong anticholera serum should be used. We use the serum derived from hyperimmunized rabbits. This serum in Ceylon generally shows an agglutination limit which varies between 1 in 5,000 and 1 in 7,000 on the various strains of cholera vibrios kept in stock in the laboratory. Any vibrio found in stools which is agglutinated by this serum in a dilution not less than 1 in 4,000 can safely be considered, as a rule, to be the true germ of cholera. In doubtful cases, all the cultural characters should be studied, and Pfeiffer's test and Castellani's absorption test should be carried out.

Dunbar has recommended a special agglutinative test, which consists in mixing directly a drop of the stools with diluted immune serum. The cholera vibrios become agglutinated. This process is practicable only when the stools contain many vibrios.

3. Inoculate four tubes of peptone-water with the suspected stools, the first with one loopful, the second with two, the third with three, and the fourth with four; or inoculate each of two Erlenmeyer flasks, capped with sterile filter-paper without wool-plugs, with 1 c.c. of the stools. The formation of a scum on the surface of the medium within eight to ten hours is suspicious of cholera. The pellicle and the upper portions of the medium should be examined microscopically for the presence of vibrios, and Mackonkey agar or ordinary agar plates should be made for further examination, as already described. The peptone-water should be tested for the presence of indol, adding a few drops of pure sulphuric acid. In true cholera the indol reaction is generally present eight to ten hours after inoculation.

4. Inoculate the surface of three ordinary serum-tubes with the suspected stools, and incubate at 35° C. If within sixteen hours there is no zone of liquefaction in the medium, cholera may be practically excluded. If there is liquefaction, this may be due to the presence of the cholera or other serum-liquefying germs, or to the stools containing an amount of proteolytic substances. The liquefied serum may be plated on Mackonkey or ordinary agar plates, and any suspicious colony further investigated.

5. Dieudonné's special strongly-alkaline blood agar may be used for the isolation of the cholera vibrio in fæces. On this medium the cholera germ grows well, while the coli and coli-like organisms scarcely vegetate. Of course the colonies which grow must be carefully investigated, as already described.

If material has to be sent to a central depot for bacteriological examination, certain precautions must be carried out. The fæces must be carefully collected, if possible into a bed-pan which has been scalded or boiled, or a loop of small intestine carefully removed post mortem. These specimens must be forwarded in a glass bottle, which, as well as the cork, has been boiled. It is, perhaps, hardly necessary to state that no antiseptic must be mixed with the specimens.

Prognosis.—The prognosis is usually bad at the beginning of the epidemic, but improves as the epidemic continues. The case-mortality may be stated to be on the average about 50 per cent.

Treatment.—The treatment of cholera must aim at the destruction and removal of the vibrios, the neutralization of the toxins, the prevention of secondary infection through the damaged intestinal mucosa, the healing of which must be assisted, and the relief of symptoms.

To promote these objects, the patient must at once be sent to bed, no matter how slight the attack may seem to be. His room should be airy, and he should not be allowed to leave the horizontal position. The bed-pan and urine bottle must be used, and the former should be slightly warmed.

The bowel should be cleansed by a dose of ½ ounce of castor oil made into an emulsion and combined with chloroform. If this dose is vomited, it must be repeated.

This preliminary purgation must be followed by a dose of calomel, usually from 3 to 5 grains, which preferably should be combined with 6 to 12 grains of sodium bicarbonate, which assists its action. After this initial large dose, calomel should be continued in smaller doses, either $\frac{1}{10}$ to $\frac{1}{20}$ grain every half or quarter hour, or $\frac{1}{4}$ grain every hour, until either the symptoms begin to improve or the patient passes into the algide stage. Hypodermic injections of morphia (gr. $\frac{1}{4}$) are useful to allay vomiting and to relieve the pain of the cramps.

Bakaleinik recommends the administration of castor oil with salicylic acid and naphthalin. His formula is:

Acidi salicylici	0·60 gramme.
Naphthalin	0·25 gramme.
Olei ricini	30·00 grammes.

The ingredients to be well triturated for half an hour.

The patient must be kept warm, and supplied with plenty of water to drink, which preferably should be taken in sips, and sinapisms or turpentine stupes should be applied to the abdomen.

When collapse has set in, hot bottles must be applied to the extremities and round the body, and when the pulse fails, the median cephalic vein should be opened at the elbow, and Rogers' special silver cannula, made by Messrs. Down and Company, inserted, and through this injections of hypertonic saline solution should be injected until the blood-pressure returns as tested by the pulse, or more preferably by a Riva-Rocci's instrument.

The saline solution at present recommended by Rogers and Mackelvie is stronger than that generally used, but will probably be more useful. These saline injections are made of a 1·25 per cent. solution of salt, which is prepared by dissolving 2 drachms of salt in 1 pint of water, sterilizing carefully, and injecting 10 to 40 ounces at a temperature slightly in excess of that normal for the blood. These injections may have to be repeated several times, and therefore the cannula must be left *in situ*. At the same time, hypodermic injections of strychnine, with or without atropine, should also be given, and warm rectal injections.

During this treatment the bladder must be carefully watched to see whether urine is being passed or not, and if suppression occurs, dry-cupping should be performed over each loin.

When the stage of reaction sets in, a mixture containing salicylate of bismuth gr. xv., bicarbonate of soda gr. v., liquor opii sedativus min. v., mucilige q.s., and chloroform water 1 ounce, should be given, and later one containing alkalis and digitalis is useful.

With regard to symptoms, the persistent vomiting may be relieved by small pieces of ice or by $\frac{1}{8}$ grain of cocaine dissolved in a teaspoonful of water, or by a dose of 10 minims of mistura pepsini composita et bismutho every half-hour until four doses have been given, or by one or two drops of tincture of iodine in water. Cramps are treated by massage, assisted by rubbing with dry powdered ginger, by hypodermic injections of morphia, or by inhalations of a mixture of chloroform and oxygen. Prostration must be combated by hypodermic injections of strychnine or of camphor in ether. Delirium must be relieved by bromides with tincture of hyoscyamus.

The treatment of complications, such as pneumonia, etc., must be conducted on the lines laid down in textbooks on general medicine.

Other methods of treatment may be briefly mentioned. Many disinfectants are recommended by different authors—*e.g.*, a mixture of sulphocarbolates of zinc, 2 grains; soda, 2 grains; calcium, 3 grains, dissolved in peppermint. Acetozone, alphazone, and medical cyllin are recommended by O'Gorman, and both he and Waters advise the administration of 15 minims of medical izal dissolved in 1 ounce of water every two hours. Salol has been strongly recommended by some writers, and Brown and Banerji praise an emulsion of eucalyptus oil with mucilage and syrup of lemons, of which 5 minims are given for a dose. O'Gorman advises copper arsenite for infants, while Duke recommends red iodide of mercury in the algide stage, and Chosky cyanide of mercury in $\frac{1}{10}$-grain doses in syrup and water every two to three hours, but says this is apt to cause stomatitis during convalescence, which can be avoided by regulating the doses. Cantani long ago advised slow intestinal injections of 3 to 4 pints of a 1 per cent. solution of tannin, with or without 20 to 40 drops of tincture of opium, and warmed to 100° F. and given every three to four hours. Denier's serum treatment has been found useless by Strong, but Kolle's serum promises to be more useful. Several authors recommend treatment by repeated hypodermic injections of morphia.

With regard to diet, no food should be given during the acute attack, but merely liquids, which should consist of water, iced water, iced soda-water. Stimulants should only be given with great moderation, and carefully by the mouth, as at times they are apt to do more harm than good. In the algide state the liquids given should be warmed, and hot black coffee may be used as a cardiac stimulant.

When reaction sets in, only the mildest foods must be allowed, and then only with care. Begin with thin arrowroot, and continue with milk mixed with soda-water, and then with milk, barley-water, rice-water, etc. Sanatogen, plasmon, and somatose are also recommended. Meat-extracts should be avoided. As improvement continues, the diet may be slowly and carefully increased, but the greatest care must be taken for a long time.

Prophylaxis.—The prophylaxis must be based upon the knowledge that the disease is carried by man, and is spread from one man to another by water, milk, contaminated food, especially green vegetables, and insects, especially flies and perhaps ants.

The methods which may be adopted are classifiable into private and public.

Private Methods.—At the beginning of an epidemic it is as well to circulate a printed notice in English and in the vernacular telling the householder what he should do to prevent the disease attacking his household. It is the duty of the head of every household to personally inspect twice a week at least his kitchen and go-downs, and especially his servants' latrines, and to see that the house and compound are kept in a clean, sanitary condition. He must also see that the filters are properly cleaned, and should flies abound in the house, their source should be diligently sought for, or, if it cannot be found and dealt with, the Sanitary Authority should be informed. He should also see that the whole household keep themselves strictly clean, especially the cooks.

With regard to food and drink, care should be taken that all cooking and serving vessels are thoroughly cleansed with boiling water, and that kitchen-cloths are washed in a solution of cyllin or carbolic acid. Especial care should be taken with regard to the ice-safe, which is apt to become coated internally with green slime, which may cause diarrhœa. This ice-safe must be thoroughly cleaned with hot soda and water, and exposed to the sun at least once a week. Food must not be stored near latrines, and must be protected from flies and ants, and the rooms and cupboards in which it is placed must be thoroughly cleansed with soda and hot water at least once a week.

All water must be boiled and filtered, and stored in covered vessels, and all milk must be boiled and carefully protected from flies and other insects. Care should be taken that good milk is procured. No uncooked vegetables or salads should be used; fruit must be sparingly indulged in; and unripe fruit, especially melons, must be avoided. Balfour advises that jellies in particular should not be used during a dangerous season. Weak tea and lime drinks made with boiling water should be used as beverages.

All cases of illness, but especially diarrhœa, must be promptly treated by a medical man.

With regard to prophylactics, eucalyptus oil in 10-minim doses twice daily has been strongly recommended by some authors, but the most usual prophylactic is a protective inoculation, which was first introduced by Ferran in Spain, and has been studied and improved by Haffkine and Gamaleia; by Tamancheff, who added 0·5 per cent. carbolic acid to the sterilized prophylactic; and by Strong and others.

Haffkine originally used two prophylactics—a weak and a strong—with the idea that the strong would produce too violent a local reaction; but this proving to be wrong, only the strong is now used. This prophylactic is prepared by intensifying the virulence of the vibrios by passing them through a series of rabbits, and then growing on agar, from which the growth is washed off by sterile broth which is made up to 8 c.c., of which one is injected hypodermically into the flank as a dose. There is some local reaction in the form of redness, swelling, and pain, and some general febrile reaction. The result is that after an initial diminution of the resistance against the disease this becomes considerably increased after the fifth day. Haffkine's statistics show that it diminishes by one-tenth the liability to the disease, and increases the chance of surviving if attacked. Thus, according to Powell, in 6,549 non-vaccinated there were 198 cases and 124 deaths; and in 5,778 vaccinated there were 27 cases and 14 deaths. Vaccination confers a partial immunity, which lasts about fourteen months, after which it diminishes, and finally disappears. Revaccination is, therefore, necessary after this period.

Strong's method is to spray agar which is contained in large flat-sided flasks with a twenty-hour-old culture of the vibrio in broth, and then to incubate the flasks at 37° C. for twenty hours, and to suspend the subsequent growth in sterile water, which is first heated to 60° C. for one to twenty-four hours, then incubated at 37° C. for two to five days, and then filtered through a Reichel candle. Two c.c. (the equivalent of 10,000 units of immunity in a rabbit) of the filtrate, which must be sterile, are inoculated. This prophylactic, which is said to be capable of being kept for a year, produces no local reaction, and but slight general reaction, and increases the bactericidal and agglutinative powers of the serum considerably. Strong considers that it contains receptors separated from the vibrios, and that it probably acts by increasing the bactericidal and antitoxic powers of the epithelial cells of the mucosa of the alimentary canal.

Public Prophylaxis.—It is the duty of the State to attempt to ward off cholera by preventing human beings introducing the germ. This involves the careful watching of the frontiers, especially along the lines of intercommunication, whether roads, railways, or waterways. Under the last heading must be included ships, boats, and rafts, for it must be remembered that cholera is very apt to be introduced by persons travelling along rivers.

Any suspicious case must be detained for five days in quarantine in suitable isolation hospitals erected near the frontiers, while the sick must be tended in special hospitals with all the precautions to be mentioned later.

Merchandise does not, as a rule, require any disinfection, unless there is reason to suspect that some of it has been fæcally contaminated from a case.

When an epidemic begins, the first duty is to form a special Cholera Board to deal with the outbreak, and this Board should be composed of financial and legal authorities, as well as of doctors and bacteriologists. This Board will form the central authority for the control of the epidemic. All suspicious cases must be reported to this central authority at once.

Then central and outlying bacteriological stations must be provided, and special hospitals and isolation hospitals built, and, if possible, nurses and medical men obtained who have some practical knowledge of the disease. If time permits, it is as well to have these vaccinated against the disease, but it should be remembered that five days must elapse before the immunity is effective.

Arrangements must then be made for the prompt bacteriological diagnosis of cases, for the prompt treatment of all disorders, especially intestinal, and extra dispensaries must be opened, and the public informed of the necessity of availing themselves of these medical arrangements. If necessary, a house-to-house inspection should be made, in order to find out if there are mild concealed cases, and nobody should be buried without a proper medical certificate.

All patients must be removed to the hospitals, and the houses disinfected with the Clayton gas apparatus, in order to kill not merely the germs, but also the flies and ants. If this is not available, formalin sprays, together with burning sulphur, may be used. Fomites should be carefully disinfected, and persons attending the sick must avoid infection by careful disinfection of the hands and by wearing overalls.

The dejecta of patients should be carefully disinfected with cyllin or carbolic acid, and no patient should be liberated from the hospital until bacteriological examinations of his fæces on three successive days are negative. This is a most necessary precaution, because otherwise he may spread the germs broadcast for a period of about six weeks at least.

Care must be taken to disinfect and bury the dead with least chance of the infection spreading. Cremation should be encouraged in preference to burial.

A systematic search must be made for the origin of the infection, and drinking-water, well-water, etc., must be regularly examined bacteriologically. Dangerous wells must be closed, and all wells may be Hankenized—*i.e.*, disinfected with permanganate of potash.

The milk, ice, and aerated waters should be taken under the municipal control, and not merely must care be taken that they are pure, but they must be tested bacteriologically from time to time.

Vegetables must be inspected, and the place where they are grown ascertained and inspected, in order to find whether there is fæcal pollution. A crusade must be made against flies and dirt in general. The disposal of sewage should, of course, have been dealt with before the epidemic has occurred; but if it is defective, attempts should be made to remedy this as far as possible, and a scheme at once started for proper collection and disposal.

Bathing-places must be carefully inspected, and bad places closed, and only pure water allowed to be used. No washing must be allowed near wells. Drugs must be given free, and means for inoculation of the prophylactic provided on a large scale.

When the epidemic is past, the sanitary defects found out during ts course should be remedied, and not forgotten until another outbreak occurs.

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CHAPTER XLV

THE DYSENTERIES

The term 'dysentery'—Dysentery and dysenteric diarrhœa—Dysenteries caused by animal parasites—Protozoal dysenteries—Entamœbic dysentery—Laveranic dysentery—Leishmanic dysentery—Ciliar dysenteries—Flagellate diarrhœa and dysentery—Spirochætic dysentery—Platyhelminthic dysenteries—Nemathelminthic dysenteries—Arthropodic dysenteries—Dysenteries caused by bacteria—Pseudo-dysenteries—References.

The Term Dysentery.—The term 'dysentery' is derived from δυσεντερία, signifying a bowel trouble, and was first employed by Hippocrates. As used at present, it covers a large number of distinct affections, induced by various species of animal and vegetal parasites. In England it used to be called the *Bloody flux*, in France *Ténesme*, and in Italy *Flusso sanguigno*. The Latin equivalent is *Tormina*, the German *Ruhr*; while the native terms applied to it are too numerous to be considered here, but we may mention the Sinhalese term *Lehedanpachanai* (*Leh* = blood, *hedan* = mucus, *pachanai* = diarrhœa), and the Indian term, *Rattam-seedam-banthala-porado* or *Wayatholechell*.

Dysentery and Dysenteric Diarrhœa.—The occurrence of a bowel disease in which blood appeared in the motions was well known to the ancients, for descriptions of such a condition can be found in the works of the old authors Charaka and Susruta, in which dysentery is called 'Atisar,' and acute dysentery 'Ama-apaka,' while the chronic variety was called 'Pakitsar.'

Hippocrates recognized two distinct types of disease of the bowels—one characterized by the number and fluidity of the motions, which he called διαῤῥοέα, and the other, which he termed δυσεντερία, by the presence of blood in the motions.

At first the term 'dysentery' included any disease in which there was a discharge of blood *per anum*, but Aretæus, Galen, and other ancient physicians, soon differentiated the disease more clearly by emphasizing the fact that there should be mucus as well as blood in the motions, and that the symptoms of tormina and tenesmus must be present. They further stated that the disease was due to an ulcerated condition of the bowels. Hence, according to these ancient writers, in order to make the diagnosis of dysentery, it was necessary to have blood and mucus in the motions. Recent investigations have, however, shown that certain cases of diarrhœa and dysentery are brought about by the same organism, and that a form of diarrhœa which may be called dysenteric diarrhœa is only one phase of the clinical appearances of a dysentery, and is ætiologically in no way different from what might be termed a true dysentery, except in the severity of the symptoms and the post-mortem appearances. Briefly, certain forms of diarrhœa are dysentery under a somewhat different clinical aspect. Hence it is not expedient to attempt to classify dysenteries by their clinical symptoms, or by their post-mortem appearances, and any rational classification and description of the complaint must be based on the causation.

We therefore classify dysenteries and dysenteric diarrhœas into—

A. Dysenteries caused by Animal Parasites:
   I. The Protozoal Dysenteries.
   II. The Platyhelminthic Dysenteries.
   III. The Nemathelminthic Dysenteries.
   IV. The Arthropodic Dysenteries.
B. Dysenteries caused by Bacteria.
C. Pseudo-dysenteries.

By the last expression we mean such forms of the complaint as may be due to the irritation of fish-bones, glass, cancer, or inflammations of organs adjoining the alimentary canal.

A. DYSENTERIES CAUSED BY ANIMAL PARASITES.

I. THE PROTOZOAL DYSENTERIES.

The protozoal dysenteries are classified into:

(*a*) Entamœbic Dysentery.
(*b*) Laveranic Dysentery.
(*c*) Leishmanic Dysentery.
(*d*) Ciliar Dysenteries.

It is convenient to describe as an appendix to these dysenteries the diarrhœas said to be due to flagellate organisms, though these can in no way clinically be termed dysentery, and also the so-called spirochætic dysentery.

(*a*) Entamœbic Dysentery.

Synonyms.—Entamœbiasis, Amœbiasis, Amœbic Dysentery.

Definition.—Entamœbic dysentery is an acute or chronic specific disease of the intestine, caused most commonly by *Entamœba histolytica* Schaudinn 1903, and by *E. tetragena* Viereck 1907 in some cases, and possibly by other species. These Entamœbæ enter the body with food or water, and produce colitis, rectitis, and enteritis, characterized by the passage of frequent motions, which generally contain blood and mucus, and are associated with abdominal pain and tenesmus. At times they also produce abscesses in the liver and other parts of the body.

History.—In 1860 Lambl noticed amœbæ in the motions of a child suffering from diarrhœa, and in 1870 Lewis found the same organisms in the motions of cholera patients; while Loesch, in 1875, gave a careful description of certain Amœbæ which he found in the motions of a man suffering from chronic diarrhœa. Loesch's drawing signifies that he saw both the organism which we call *Entamœba coli* and that which we now name *Entamœba histolytica.* Further, he found that solutions of quinine of a strength of 1 in 5,000, when injected *per rectum*, temporarily benefited his patient, who, however, subsequently died of pneumonia, when a post-mortem revealed that the bowels were ulcerated. Loesch was able to infect dogs; but, on the other hand, Grassi, and later Cunningham and Lewis, showed that the motions of healthy people also contained Entamœbæ. Koch, in 1883, found Amœbæ in the ulcers in cases of dysentery in Egypt, and Kartulis began a series of investigations, which finally ended by his defining the types of dysentery as 'endemic,' due to amœbæ, and 'epidemic,' due to bacteria. In 1891 Councilman and Lafleur introduced the term 'amœbic dysentery,' and Hlava, Quincke, Roos, Vivaldi, and many others published experimental researches on the infection of animals by amœbæ and the production of dysentery.

In the meanwhile a prolonged discussion took place, some observers denying, and others asserting, the pathogenicity of the amœbæ. Kruse and Pasquale were the first to throw light upon this difference of opinion by suggesting that both theories might be correct, and that there might be two species of amœbæ, one pathogenic and the other harmless; but this was not finally settled until the researches of Casagrandi and Barbagallo, together with those of Jürgens, were confirmed and greatly extended by Schaudinn, who showed that there were two forms of amœbæ quite distinct from one another—viz., an *Entamœba coli* Loesch, which was harmless, and another, *Entamœba histolytica* Schaudinn, which was the true cause of entamœbic dysentery. Since that date the labours of Viereck and others have demonstrated the pathogenicity of *Entamœba tetragena*, while Lesage has shown that species of harmless Entamœbæ other than *Entamœba coli* may exist in the tropics. Gauducheau has isolated from a case of dysentery a small amœba which he calls *E. phagocytoides*, and which we have described in Chapter XI., in which *E. minuta* and *E. nipponica* are also described.

Climatology.—Entamœbic dysentery is found throughout the tropical world, and also occurs in the Temperate Zone. In general terms it may be stated that entamœbic dysentery is common in tropical and subtropical Africa, especially in Senegambia, Algeria, and Egypt. It is common in Mauritius and Ceylon, and is possibly not as rare in India as it is alleged to be. It is common in China, Indo-China, and the Philippines, and not infrequent in North America, but is said to be rare in Central America, in the West Indies, and the Guianas, while common in Brazil and Chili. In Europe it is endemic in Russia and Germany, and fairly frequently met with in the south, especially in Italy.

Our observations do not lend support to the theory that entamœbic dysentery is more common in the hills than in the plains of the tropics, as we have frequently met with it in persons residing in the low country. We have noted the disease all the year round, but it would appear to be more prevalent towards the end of the dry and the beginning of the wet seasons, which probably merely means that the chance of drinking polluted water is greater at that time, for though the climatological characters are not well understood, the disease appears to bear a constant relationship to contaminated water.

Entamœbic dysentery is generally endemic, and does not spread in epidemic, still less in pandemic, form. Probably, as medical science advances, it will be found to be of more frequent occurrence and of wide distribution.

Ætiology.—Entamœbic dysentery is caused by *Entamœba histolytica* Schaudinn 1903, by *Entamœba tetragena* Viereck 1907, by *E. minuta* Elmassian 1909, and possibly by other Entamœbæ, for Noc has described cases of dysentery caused by an Entamœba morphologically similar to *E. histolytica*, but easily cultivated. The life histories of the various species, as far as they are known, have already been described in Chapter XI. Musgrave's researches in Manila point to the fact that the most common source of these parasites is the drinking-water, but it is possible that contaminated food, and especially green vegetables, may play an important part in their dissemination.

There does not appear to be any well-established racial or age predispositions, but the disease is less common in women than in men, perhaps because they are in some way less exposed to infection.

Pathology.—The spores of the Entamœbæ enter the body usually by the drinking-water, and less frequently by food, and produce the young Entamœbæ on arrival in the large bowel. These young forms enter the mucosa, probably by passing between the cells lining Lieberkuhn's follicles, and then, entering the lymphatics, make their way through the muscularis mucosæ into the submucosa, where they live and feed upon the tissue cells, red cells, and perhaps leucocytes. They, however, invade not merely the tissue of the submucosa, but also the radicles of the portal vein, and at times the branches of the mesenteric arteries, in which they may cause thrombosis. From the radicles of the portal vein they may be carried to the liver, and cause hepatitis and hepatic abscess.

In the submucosa they induce cellular and œdematous infiltrations, which cause the mucosa to project in the form of small elevations, which generally show a minute blackish point or slough at the summit. This slough is cast off, and a small ulcer is formed, which rapidly deepens until it extends into the submucosa. These ulcers become infected with bacteria, and quickly extend by the joint action of the bacteria and the Amœbæ forming roundish or oval ulcers with undermined edges; in the latter case the long axis of the ulcer lies transverse to the direction of the bowel. These ulcers may deepen until the muscular and the peritoneal coat is exposed, and even perforated, which, of course, leads to peritonitis or abscess formation, according to the position of the perforation.

Entamœbic dysentery would appear to undergo in many cases no spontaneous cure, but may at times remain quiescent, forming a type of latent amœbic dysentery, which may be found accidentally while performing an autopsy. When the ulcers heal, which they do by the formation of connective tissue, a distinct scar is formed, which is often black in colour from the action of the sulphuretted hydrogen of the bowel upon the iron of the blood. When cicatrization takes place, the lumen of the bowel may be constricted, causing stenosis and obstinate constipation. Peritonitic adhesions are also very common, binding the large bowel to the viscera or walls of the abdomen and pelvis.

Sometimes, when the infection is severe, the bowel becomes gangrenous; at other times the Amœbæ may be carried to the liver or other parts of the body, and form abscesses, which, though most commonly met with in the liver, may still occur in the spleen, the salivary glands, and elsewhere.

Morbid Anatomy.—Usually the body of a person dying from entamœbic dysentery is emaciated, and the abdomen is sunken. Rigor mortis begins, and passes off early, and decomposition sets in quickly. On opening the abdomen, it is noticed that the tissues are dry, and that a peculiar odour is perceived; the omentum may be normal or congested, and may or may not be adherent. The coils of the small intestine are usually normal, but may be congested. The large intestine is generally contracted and thickened, but may be gangrenous in places or along its entire length. There may be perforation and purulent peritonitis. The mesocolon may be congested, and œdematous or thin and fibrous, and adhesions to various organs may be noted. The mesocolic glands are usually enlarged and hyperæmic. The colon may be found adherent to the liver, the spleen, or the wall of the pelvis, while internally the mucosa will be found to be reddened and inflamed, and to show more or less numerous areas of ulceration and infiltration. These areas are most commonly found in the cæcum, the hepatic flexure and the sigmoid colon, but may occur anywhere along the course of the large intestine. In places small nodules surrounded by a ring of dilated vessels may be observed, between which the mucosa may or may not be normal, while the nodules may show superficial or deep ulceration. Deeper circular or oval ulcers may be noted with their surface covered with a dark reddish slough, their edges undermined, and their base formed by the muscular coats. In the case of the oval ulcers, the longer diameter lies transverse to the long diameter of the bowel, as a rule. The peritoneal coat may be normal, inflamed, or softened and gangrenous. Usually the muscular coat is thickened, as are the remains of the submucosa. Scrapings from these ulcers reveal blood cells, leucocytes, bacteria, and Entamœbæ. The small intestine may show small bright red nodules, and the Peyer's patches may be enlarged. The vermiform appendix is usually normal, but occasionally may be ulcerated.

The liver is often fatty, but may be congested and inflamed, or may show one or more abscesses. The pancreas is generally normal, but may be cirrhotic in chronic cases. The spleen is also usually normal, but may contain an abscess; the kidneys often show signs of parenchymatous inflammation. The heart and lungs are generally normal, but the former may be fatty or show brown atrophy, and the latter, especially the right lung, may show a hepato-pulmonary abscess.

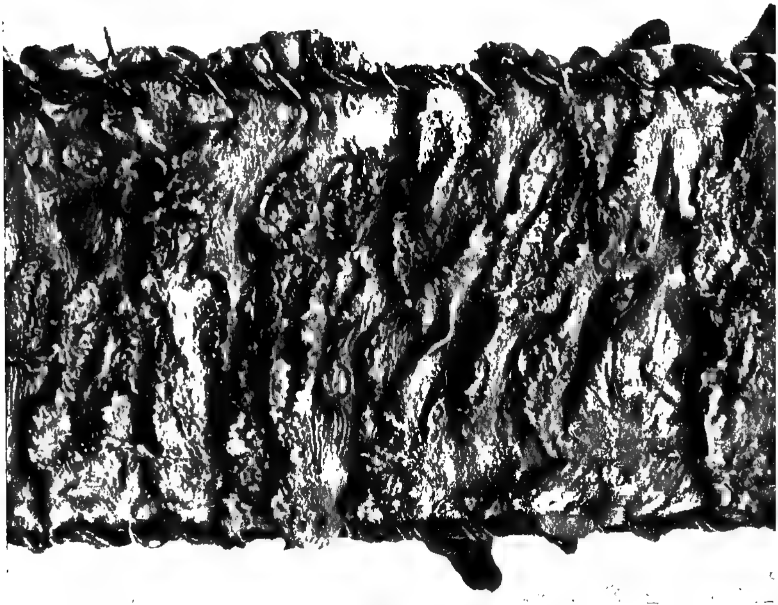

FIG. 336.—THE COLON IN A CASE OF ENTAMŒBIC DYSENTERY.

Symptomatology.—The symptomatology of entamœbic dysentery may be classified into—

1. Acute Type.
2. Chronic Type.
3. Latent Type.
4. Mixed Type.

1. *Acute Type.*—The onset is abrupt, but may occasionally be preceded for a few days by slight diarrhœa, alternating with constipation. Pain is felt in the lower part of the abdomen, which may become very severe, while the motions are attended with much griping and straining. These motions, which rarely exceed thirty *per diem*, contain blood and mucus, and occasionally greenish material, and when examined by the microscope reveal leucocytes mucus, Charcot-Leyden crystals, Entamœbæ, bacteria, and at times shreds of tissue.

The tongue is moist, and often coated with a white fur, and there is usually anorexia, and there may be nausea and vomiting, while digestion is usually much impaired. The abdomen is sunken, the liver and spleen normal, but tenderness is felt on pressure along the whole or a part of the large bowel.

The examination of the heart and lungs reveals, as a rule, no abnormality, but the pulse and respirations are quickened. The microscopical examination of the blood usually shows that the red cells are diminished, and sometimes that there is leucocytosis (upwards of 20,000 per cubic millimetre), and at times, as first pointed out by Billet, the number of eosinophiles is distinctly increased, even when there is no concomitant helminthiasis.

The urine is diminished in quantity, and sometimes contains albumin and casts; but the skin is generally normal, though there is often some fever of a remittent type, which, however, may be entirely absent.

When the temperature falls to normal, and the pain and tenderness abate, these may be favourable signs, or may be merely a prelude to a gangrenous complication or a hæmorrhage. If recovery is to take place the motions become less frequent and more fæculent, and contain less blood and mucus, and gradually improve until normal motions are passed. If death takes place, which usually happens about the end of the first week, and ten days from the commencement, it is generally caused by exhaustion, or much more rarely by perforation and peritonitis or hæmorrhage.

2. *Chronic Type.*—This may follow an acute attack, or, in many cases, may begin quite insidiously, the symptoms being merely those of diarrhœa, associated at times with abdominal pain and the passage of fæculent motions mixed with mucus and sometimes streaked with blood, while in the intervals between these exacerbations there may be constipation. An exacerbation is usually ushered in by pain in the abdomen, slight fever, griping, and tenesmus, and passage of blood and mucus in the motions, while the fæces contain small greyish masses, in which the Entamœbæ may be found. The number of motions *per diem* is not excessive, and may be only twelve to fourteen. Usually they are passed somewhat more frequently at night than in the day. Gangrenous complications may, however, occur at any time in the course of an exacerbation, or, indeed, during any stage of this type, when large sloughs, smelling offensively, may be passed with the motions. Chronic

dysentery may persist for years, and cause the patient to slowly emaciate.

3. *Latent Type.*—We have several times met with cases in which, though dysenteric symptoms were absent, still, Amœbæ were present in the motions, and others in which dysenteric ulcers were only discovered accidentally on post-mortem examination, the death being due to other causes. This latent condition is important, as it can easily lead to an acute attack or to liver abscess, and no doubt these 'entamœbic carriers,' as has been noted by Martini, Vincent, and others, are a source of the dissemination of the infection.

4. *Mixed Type.*—These are cases in which there is a mixed infection of *Entamœba histolytica* and the Shiga-Kruse bacillus. Usually in these cases the motions are numerous from the first, and there is considerable fever, nausea, vomiting, and great constitutional disturbance. The motions are apt to be very offensive, and to contain sloughs, indicating a gangrenous condition of the bowel. Exhaustion may come on early, and the patient may die delirious or comatose, or, more rarely, from peritonitis, with or without perforation. More rarely improvement sets in, and the disease becomes chronic.

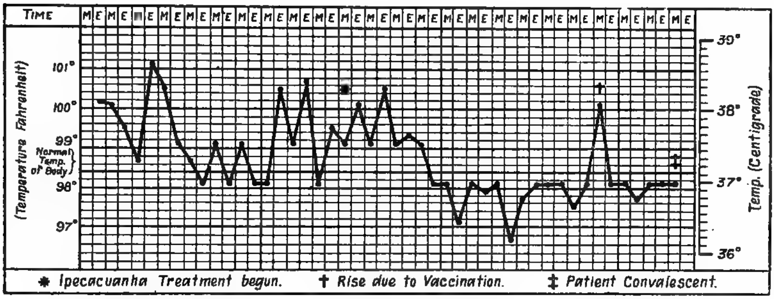

FIG. 337.—ENTAMŒBIC DYSENTERY COMPLICATED BY HEPATITIS.

Complications.—The most usual complication is hepatitis and hepatic abscess; more rarely gangrene of the bowel and peritonitis may supervene during an attack; while hæmorrhage is a most unusual complication. The hepatitis is recognized by the tenderness in the right hypochondrium and by the rise in the temperature, but it and the hepatic abscess will be discussed in a subsequent chapter.

Sequelæ.—The important sequel to an attack of entamœbic dysentery is liver abscess, but abscesses in other parts of the body such as the spleen may be met with. Stenosis of the sigmoid colon, due to the cicatrization of the healing ulcers, is well known, and will be dealt with under the heading of Bacterial Dysentery. Sprue is often said to be a sequel of dysentery, but this must be considered to be doubtful.

Diagnosis.—The diagnosis between bacterial and amœbic dysentery by clinical phenomena only is, in our opinion, impossible in most cases, though several observers have attempted to define several differential points. These authors state that entamœbic dysentery is to be distinguished from bacillary dysentery by its chronic course, its rare pyrexia, and the absence of toxic symptoms while it is often followed by liver abscess. Apart from the last feature, the other so-called differential signs have, in our experience, no importance, as we have come across extremely acute cases of entamœbic dysentery with fever and toxic symptoms.

The only certain method of diagnosis is by the discovery o *Entamœba histolytica,* or more rarely *E. tetragena* in the stools. It is practically important to distinguish between *E. histolytica* and the harmless *E. coli.* The former is larger, and possesses an ectoplasm, which is easily differentiated from the endoplasm ; it is more actively motile than *E. coli,* and often contains erythrocytes and bacteria. The nucleus of *E. histolytica* is eccentric, small and generally indistinct, does not stain deeply, and has very little chromatin.

Prognosis.—The prognosis in a case of entamœbic dysentery must always be guarded, as there is the possibility of hepatic abscess as sequela of the mildest case. The prognosis is worst in the gangrenous cases, better in the acute, and still better in the mild chronic cases, but the danger of latency after an apparent cure must be remembered. In the acute type hiccough is an unfavourable sign, often indicating the approach of exhaustion and death.

Treatment.—It is of the utmost importance that the patient should be placed at rest in bed. For the same purpose the urine bottle and the bed-pan must be used. It is advisable to relieve the severe griping and straining by either a hypodermic injection of morphia or by small enemata of 40 minims of laudanum in 1 ounce of mucilage of starch, or by using a morphia (gr. ¼), or codeine (gr. ¼) suppository.

At first the bowels should be swept clean by a dose of castor oil (ʒiv. to vi.), with or without a few minims of liquor opii sedativus or a few doses of saline may be given during the first twenty-four hours (see Bacillary Dysentery). After the castor oil has acted, ipecacuanha should be administered in 5-grain doses every three or six hours, or in larger doses (gr. x. to xx.) twice daily, given either in the form of 'membroids' or as pills coated with salol varnish or keratin. Our experiments *in vitro* tend to show that membroids and salol varnish do not dissolve freely in peptic juice, while they do so in pancreatic juice. The salol varnish was very efficient, but care must be taken that too thick a coating is not used, as it may not dissolve in pancreatic juice. Practically, however, in man the membroids are better than the salol varnish. In this way the nauseating effects of the ipecacuanha are often avoided without diminishing its efficiency, which is the result of using the deemetized drug. Administered in the above methods, there is, i most cases, no fear of nausea, and the precautions usually advise need not be carried out. Rarely the membroids and salol varnishe pills may be passed unaltered in the motions, and in such cases th drug should be given in cachets or in suspension in mucilage an chloroform water. When these are not obtainable, ipecacuanha ma be given in cachets or pills (gr. x. to xx. twice a day), and shoul be preceded a quarter of an hour by a dose of 15 minims of tinctur of opium, in order to prevent the possible vomiting.

When the acute symptoms have passed away, intestinal irrigations are useful, and should be administered every other day, o once or twice daily. We generally use a solution of tannic aci (3 to 5 in 1,000), or a solution of the bihydrochloride of quinine i varying strength from 1 in 5,000 to 1 in 750. About ½ to 3 pint should be very slowly injected by gravity from a glass douch vessel by means of a long soft rectal tube well greased with bori vaseline. This injection may be preceded by a cocaine or morphin (gr. ¼) suppository introduced half an hour previously.

Other substances used for rectal irrigations are: Acetozone (1 in 2,000) alphozone (1 in 2,000); argentum nitras (1 in 2,000, 1 in 1,000), useful i some very chronic cases; protargol (1 in 500). Creosote is recommended b Zanardini, and may be used by injecting 2 pints of 1 in 300 or 1 pint of 1 i 100. The injection, however, may be followed by symptoms of absorption—*e.g.*, dyspnœa and faintness. A solution of sodium hypochlorite may b used: two pints of 8 to 12 in 1,000 being recommended by Vincent once o twice a day, which is also useful for entamœbic carriers.

In gangrenous dysentery the only chance of saving the life of th patient is to perform the operation of appendicostomy, and irrigat the whole lower bowel with quinine lotion. The details of thi operation are given under the heading Bacterial Dysenteries With regard to the treatment of symptoms, the most important i the relief of pain by hypodermic injections of morphia or by fomentations sprinkled with opium and applied to the abdomen. As th case progresses favourably, a bismuth mixture or tannalbin i cachets (gr. xv. every two to four hours) may be given, while th irrigation may be diminished and stopped, and finally a tonic ma be prescribed.

We are strongly of opinion that the ipecacuanha should continue to be given in smaller doses long after the dysenteric symptom have disappeared, in order to prevent relapses, and possibly, also the development of a liver abscess, which is the most dangerou sequel. Among the other drugs which have been recommende in the treatment of entamœbic dysentery are *Simaruba officinali* and the so-called *Kho-sam* powder.

The former is recommended by Manson to be used as a decoctio which is prepared by taking simaruba bark, pomegranate fruit-rind, and gum arabic 15 grammes of each, and placing in a litr of warm water, which is boiled till reduced to half its bulk, and o this decoction 1 ounce is taken three or four times a day.

The latter (Kho-sam powder) is derived from the berries o *Brucia antidysenterica* and *B. sumatrana*, which grow in Indo China. It is administered in pill form, 1 grain being given two to four times a day.

If cicatrization of the colon results with stenosis, then sigmoidoscopy must be performed, and the condition treated as described under Bacterial Dysentery. Liver abscess is considered separately Abscesses in other parts of the body—*e.g.*, the spleen—are rarely met with, though it is possible that some of the inexplicable deep seated abscesses may have their causation in Entamœbæ.

The diet should be the same as that to be described presently under the heading Bacterial Dysentery. During convalescence the food must be slowly and carefully increased, no acid or very warm substances being allowed.

Prophylaxis.—The prophylaxis consists in the drinking of only boiled and filtered water, and the avoidance of salads and uncooked vegetables.

The Entamœbæ were shown to exist in the drinking-water in Manila, and it was found that copper sulphate added to the water of the large reservoirs was useless, as was a large filter-bed, and that in fact, the only safeguard was to sterilize the water by boiling.

(*b*) Laveranic Dysentery.

Definition.—An acute enteritis and colitis caused by **Laverania malaria** Grassi and Feletti, and characterized by high fever, associated with the passage of frequent motions containing blood and mucus.

Symptomatology.—The attack usually begins suddenly, with high fever great distress, and prostration. The tongue is coated, the abdomen tender and many motions are passed containing blood and mucus. Unless correctly treated, the condition becomes serious, and rapidly leads to the death of the patient.

Diagnosis.—The routine examination of the blood in all cases of tropical disease will prevent mistakes being made, as the presence of numerous subtertian parasites in the blood will reveal the nature of the complaint.

Treatment.—Quinine should be given in large doses, and the intestinal symptoms first treated with castor oil or salines, and then with astringents, such as bismuth subnitrate, tannalbin, and salol.

(*c*) Leishmanic Dysentery.

Definition.—An acute enteritis and colitis caused by *Leishmania donovanni*, and characterized by the passage of blood and mucus in the motions.

Symptomatology and Treatment.—As already mentioned in the chapter on Kala-Azar, dysenteric symptoms closely allied to true dysentery may appear during the course of that disease, and must be treated on the same lines as those laid down for the treatment of kala-azar, together with symptomatic treatment as indicated above.

(*d*) Ciliar Dysenteries.

One variety of the ciliar dysenteries may be briefly mentioned—viz., that caused by *Balantidium coli* Malmsten. Other less-known causes are *Colpoda cucullus*, *Balantidium minutum*, *Nyctotherus faba*, and *N. giganteus*.

Balantidic Dysentery.

Definition.—An acute or chronic ulceration of the large intestin caused by *Balantidium coli* Malmsten.

History.—Leeuwenhoek originally discovered the parasite *Balantidium coli*, but Malmsten described and named it. The latte observer found it in the motions of a man suffering alternately fron diarrhœa and constipation. Other cases have been recorded b Strong, Dehio, and Klemeniko.

Climatology.—The disease is known to occur in man in th Philippine Islands, Japan, and Europe, while the parasite is said t be constantly found in pigs.

Ætiology.—The cause of the disease is *Balantidium coli* Malmsten which may be different from the parasite found in pigs.

Pathology.—The method of infection is unknown. The parasit appears to enter the mucosa, in which it wanders, causing an inflammatory reaction and ulceration.

Morbid Anatomy.—The intestine may show a diphtheritic fals membrane, with usually a number of ulcers in the rectum anc colon, and on microscopical examination the parasites can be founc in the mucosa surrounded by a round-celled infiltration.

Symptomatology.—The disease is insidious in its onset, bein marked by attacks of diarrhœa, alternating with constipation anc vomiting, with anorexia and the passage of mucus in the motions Œdema of the face and limbs may set in, and death result fron exhaustion.

Complication.—The parasite may enter the liver and form cysts.

Treatment.—No treatment is known to do any good, but th symptomatic treatment laid down for entamœbic dysentery ma be tried, beginning with castor oil or salines, and followed b intestinal irrigations of tannic and boric acids or quinine. Larg rectal injections of a solution of methylene blue, 1 in 3,000, combinec with the internal administration of the same drug in 2-grain dose in cachets or pills, may also be tried.

Prophylaxis.—It is not certain that the parasite found in the pi is the same as the human parasite, and, further, the method of infection being quite unknown, no useful remarks can be made with regard to prophylaxis.

Flagellate Diarrhœa and Dysentery.

Definition.—Flagellate diarrhœa is an acute or chronic specific diarrhœa due to *Cercomonas hominis* Davaine 1854, *Trichomonas hominis* Davaine 1854, and *Lamblia intestinalis* Lambl 1859.

Climatology.—These parasites, and the diarrhœas associated therewith, appear to occur in temperate and warm climates alike. They certainly are very common in Ceylon, and have been met with in Africa and Hong-Kong. In the latter place Bell has described large parasites like encysted Amœbæ, showing circular movement, and breaking up into four pear-shaped, actively motile bodies containing a contractile vacuole, the only other parasite in the motions being *Cercomonas hominis.* We have seen similar cysts which are uninucleate, and which broke up into bodies which were obviously the *Cercomonas hominis*, with which the motion was teeming.

Smyptomatology.—When in small numbers the only symptoms are those o diarrhœa, with liquid brown motions, containing yellow flakes, which are composed of epithelial cells and leucocytes, around which the parasites are formed in large numbers. They are rarely the cause of dysenteric diarrhœa characterized by the passage of blood and mucus, and the presence of fever furred tongue, tenesmus, and abdominal pain.

Treatment.—The best treatment is to administer enemata of 3 pints o 1 in 3,000 solution of methylene blue twice daily, and to administer methylene blue (gr. ii.) by the mouth in cachets or pills. The patient should be told that the urine will become blue, otherwise he will become much alarmed

Spirochætic Dysentery.

Le Dantec has described a form of dysenteric diarrhœa due to spirochætes Further researches are, however, necessary to determine whether the spirochætes are the true ætiological factor of the complaint. In our experience spirochætes may be found in the stools of several cases of bacterial and ent amœbic dysentery, and also in normal stools.

II. THE PLATYHELMINTHIC DYSENTERIES.

Fasciolopsis buski, *Schistosomum japonicum*, and *S. mansoni* cause dysenteric symptoms, which can only be diagnosed by the discovery of the eggs in the motions. The symptoms produced by the latter worms are described in detai in Chapter XLVI., while those of the former still require detailed investigation

III. THE NEMATHELMINTHIC DYSENTERIES.

Nemathelminthic dysentery is due to the sclerostome *Œsophagostomun brumpti* Railliet and Henry 1905, immature females of which were found b Brumpt in cyst-like nodules in the cæcum and colon of a negro in Wes Africa. Similar symptoms are caused by *Œs. stephanostomum* var. *Thomas* Railliet and Henry 1909, discovered in South America by Thomas.

IV. THE ARTHROPODIC DYSENTERIES.

We have already drawn attention to the fact that diarrhœas and dysenterie may be caused by the presence of species of the Chilopoda and Diplopoda and by the larvæ of flies in the intestine, but these are rare, and have alread been sufficiently described.

B. DYSENTERIES CAUSED BY BACTERIA.

The Bacillary Dysenteries.

Synonyms. — Bacillenruhr (German) ; Dysenterie Bacillaire (French) ; Dissenteria Bacterica (Italian).

Definition.—The bacillary dysenteries are acute or chronic endemic or epidemic, specific intestinal disorders caused by severa varieties of bacteria, which are disseminated largely by means o the fæcal matter of dysentery carriers, as well as by that of person suffering from these disorders. From the sources of infection the germs are conveyed to food or drink by the agency of flies, dust surface water, and direct contact with any contaminated substance Infection usually takes place by the consumption of contaminated food or drink, more rarely by direct contact with contaminated substances. In the body the micro-organisms cause a specific inflammation of the large, and occasionally also of the small, intes tine, which is characterized by diarrhœa, usually accompanied by pain, tenesmus, and the passage of blood and mucus in the motions More rarely the bacilli cause a general septicæmia.

History.—For years the theory of a bacterial causation for dysentery found many supporters, among whom may be mentioned Klebs, Prior, Ziegler, Hlava, Chantemesse, Widal, and Grigoriew all of whom attempted to isolate a specific organism.

Maggiora, Laveran, Arnaud, and Escherich believed that the *Bacillus coli communis* was the true cause, while Celli described as the cause of the disease a bacillus fermenting glucose and clotting milk, which he called the *Bacillus coli dysentericus;* but according to his more recent description some strains produce very little or no gas in glucose media, and may not clot milk, and closely resemble Flexner's bacillus.

During an epidemic in the province of Oita, in Japan, Ogata isolated a bacillus which liquefied gelatine, stained by Gram's method, and produced intestinal ulcers in guinea-pigs and cats, a discovery which was confirmed by Vivaldi of Padua, but not by other observers.

In the same year Calmette announced that the *Bacillus pyocyaneus* was a cause of dysentery in Cochin China, an observation since confirmed by Lartigan in the United States, Adami in Canada and others, but not generally accepted.

The elucidation of the ætiology of bacillary dysentery is due to the investigations of Shiga in Japan and Kruse in Germany during the years 1898-1900. They described as the cause of the malady a short bacillus, not decolourized by Gram, not clotting milk, no producing gas in any sugar media. There was at first some difference of opinion as regards motility, but Kruse's statement that the bacillus was always non-motile has been proved to be correct Kruse was also the first observer to state that there were more than one variety of dysenteric bacilli.

In 1900 Flexner reported that he had isolated a moderately motile bacillus from cases of dysentery in Manila identical with Shiga's bacillus, and producing a severe muco-hæmorrhagic diarrhœa in a human being who was the victim of an accidental laboratory infection. This bacillus was later demonstrated to be non-motile and to differ in several respects from Shiga's bacillus, notably in fermenting certain sugar media, and could be distinguished therefrom by the different biological tests. These results have been frequently confirmed by observers in different parts of the world Strong isolated a bacillus slightly different from that of Flexner also from cases in Manila.

In 1903 Hiss and Russell separated a bacillus which closely resembles Flexner's bacillus, but fails to ferment saccharose. This bacillus is often called the Y bacillus. In 1904 Castellani isolated a bacillus from cases in Ceylon which he named the 'paradysenteric bacillus.' In the same year Duval and Schorer isolated a bacillus which they believed to belong to the dysentery group, but which fermented lactose. Several other germs have been described by various authorities, while Kruse, Flexner, Lucet, Conradi, and others have made a detailed study of the pathogenesis of the disease

Climatology.—Bacillary dysentery is found all over the world in cold, temperate, and warm climates, but especially in the latter In temperate climates the germs probably cause a type of the infantile diarrhœas, which are such potent factors in the infantile mortality of those regions, while they are also responsible for the endemic and epidemic cases so frequently met with in Europe and America.

In the tropics they are also extremely common, occurring more frequently at the end of the dry and the beginning of the wet seasons. In certain regions and at certain times the virulence of the complaint appears to be increased, the reason of which is not at present available. Probably it depends upon the greater possibility of infection, owing to the drinking-water being highly contaminated in warm weather, or perhaps to the presence of multitudes of flies. The agency of these or other factors has not been completely inquired into. Whatever the cause may be, it is well known that at times the disease may spread in epidemic form over larger or smaller areas. These epidemics may be institutional, urban, or rural, or they may attack a district, a country, or a continent. Thus, celebrated epidemics are known to have occurred in Europe in 1538, 1717-19, 1779-83, and 1834-36.

Dysentery is particularly prone to occur whenever sanitation is defective, and hence is found prevalent in lunatic asylums and in armies in times of war; and this factor appears to be more potent than any climatological cause, and, indeed, may be the principal reason why the disease is so prevalent in the tropics, though the high atmospheric temperature of these regions must assist the growth of the organisms.

Ætiology.—Bacillary dysentery is brought about by micro-organisms, which belong, or are allied, to two main types—viz.:

TYPE I. Shiga-Kruse *Bacillus dysenteriæ* (does not ferment mannite).

TYPE II. Flexner-Manila *Bacillus dysenteriæ* (ferments mannite).

These bacilli are found in the dejecta, and more easily by scraping the mucus from the surface of the bowel in a post-mortem. In addition to these main types, there are several varieties of less importance, not being so widely distributed. Some of these are:

A. Hiss's *Bacillus Y dysenteriæ.*
B. Strong-Manila *Bacillus dysenteriæ.*
C. Shiga-Tokio *Bacillus dysenteriæ.*
D. Castellani's *Bacillus paradysenteriæ.*
E. Rüffer and Willmore's *Bacillus El Tor No.* 1.

Hiss divides the dysentery bacilli into four principal groups:
Group 1. Ferments glucose only (Shiga-Kruse bacillus).
Group 2. Ferments glucose and mannite (*Bacillus Y*).

Group 3. Ferments glucose mannite and saccharose (Flexner-Strong-Manila bacillus).

Group 4. Ferments glucose, mannite, saccharose, maltose, and dextrine (Harris' bacillus, Wollstein's bacillus).

Leitz, Kruse, and Shiga have called attention to the fact that while the fermentation of mannite is a reliable means of differentiation not so much importance can be given to the fermentation of maltose, saccharose, and dextrine.

In addition to these true dysenteric bacilli, there are some so-called pseudo-dysenteric bacilli, which have been classified by Torrey into three groups—Bacillus A of Duval and Schorer, Bacillus B of Duval and Schorer, Bacillus C of Duval—all of which are grouped together by the facts that they are dysentery-like bacilli which do not produce gas, but ferment lactose, and are believed to cause diarrhœa in children. Allied to these bacilli is the so-called alkaline bacillus, which acts on dextrose, and produces an alkali in milk and other media. Flexner believes that these bacill are merely saprophytes. It is to be noted, however, that under the term 'B. pseudo-dysentericus' Kruse described a non-lactose-fermenting bacillus which is the cause of many outbreaks of asylum-dysentery in Germany. Later he used the term 'pseudo-dysentery to denote every variety of dysentery caused by bacilli other than those of the typical Shiga-Kruse strain.

Celli's *B. coli dysentericus*, according to the original description is motile, clots milk, and produces gas in some sugar media, and therefore cannot be considered to belong to the dysentery group According, however, to more recent descriptions by De Blasi and others, some strains of the *B. coli dysentericus* may not produce gas and may not clot milk, and closely resemble Flexner's bacillus.

The true dysenteric bacilli may be differentiated from one anothe by their varying fermentative actions upon carbohydrates, by agglutination, Pfeiffer's reaction, and Castellani's absorption method; and though we do not enter into particulars on bacteriological subjects, still, we consider it useful to collect in the form o a table the characters of the more important dysentery germs a well as other intestinal bacteria, emphasizing, however, the fac that the varying biological reactions of the bacilli are much mor reliable than the fermentative changes.

The dysenteric bacilli are distributed mainly by the fæces o persons suffering from the disease, but there are also 'dysentery carriers' in the true sense of the word, who are an important sourc of infection.

Strong and Musgrave have proved that infection takes place by the mouth by feeding a man with pure cultures of the dysentery bacillus, which quickly produced an attack of dysentery, characterized by motions containing blood and mucus, from which th typical bacilli were grown.

The bacilli are conveyed from fæcal matter to the mouth by the contamination of food or drink, or the utensils for preparin or serving the same. This method of infection is probably common in hospitals and asylums. Another method of dissemination woul

CULTURAL CHARACTERS OF THE PRINCIPAL STRAINS OF THE DYSENTERY BACILLI AND SOME OTHER COMMON INTESTINAL BACTERIA.

Organism.	Motility.	Maltose.	Glucose.	Lactose.	Mannite.	Dextrine.	Dulcite.	Saccharose.	Litmus Milk.	Gelatine.	Serum.	Broth.	Indole.
B. dysenteriæ (Kruse-Shiga) ..	o	{o or A SL}	A	o	o	o	o	o	{A SL ALK}	o	o	G T	o
B. dysenteriæ (Flexner)	o	A	A	o	A	o or A	o	o	{A ALK}	o	o	G T	+
B. dysenteriæ V. (Hiss and Russel)	o	o	A	o	A	o	o	o	{A SL ALK}	o	o	G T	+
B. asylum dysentery (Kruse) ..	o	o	A	o	A	A	o	o or A	{A SL ALK}	o	o	G T	+
B. asylum dysenteriæ (Eyre) ..	o	A SL	A	o	o	A SL	o	o	{A ALK}	o	o	G T	o
B. asylum dysenteriæ (Eyre) ..	o	o	A	o	o	o	o	o	o	o		G T	o
B. para-dysenteriæ (Castellani) ..	o	A SL	A	o	o		o	o	A	o	o	G T	+
B. from infantile diarrhœa (Duval Baltimore)	o	A	A	o	A	A	o	o	{A ALK}	o	o	G T	+
B. morgan No. 1	+	o	A G SL	o	o	o	o	o	o	o	o	G T	+
B. typhosus (Eberth)	+	A	A	o	A	A	o	o	A	o	o	G T	o
B. para-typhoid α (Schottmüller)	+	A G	A G	o	A G	A G	A G	o	A	o	o	G T	+
B. para-typhoid β (Schottmüller)	+	A G	A G	o	A G	A G	A G	o	{A ALK}	o	o	G T	+ (trace)
B. breslaviensis	+		A G	o	A G		A G	o	{A ALK}	o	o	G T	o
B. psittacosis (Nocard)	+	A G	A G	o	A G	A G	A G	o	{A	o	o	G T	

B. enteritidis α (Gaertner)	+	A G	A G	o	A G	A G	A G	o	A ALK	o	o	G T	±
B. hog cholera (Evans)	+		A G	o	A G		A G	o	A ALK	o	o	G T	+ (trace)
B. pyogenes fœtidus (Passet) ..	o	A	A	A	A	A	A	A	A C	o	o	G T	+
B. coli communis (Escherich) ..	+	A G	A G	A G	A G	A G	A G	o	A C	o	o	G T	+
B. coli immobilis (Durham) ..	o	A G	A G	A G	A G		A G	o	A C		o	G T	±
B. neapolitanus (Emmerich) ..	o	A G	A G	A G	A G	A G	A G	A G	A C	o	o	G T	+
B. paracolon (Day)	+	A G	A G	o	A G	A G	o	o	A ALK	o	o	G T P	o
B. paracolon (Mair)	+		A	A	A G		o	o	A C	o	o	G T	+
B. pseudo-coli (Castellani) ..	+	A G	A G	A G	A G		A G	A G	A C	o	o	G T	+
B. cloacæ (Jordan)	+	A G	A G	A G	A G	A G	o	A G	A C	+	±	G T	±
B. acidi lactici (Hüppe)	o	A G	A G	A G	A G	A G	o	o	A C	o	o	G T	+
B. lactis aerogenes (Escherich) ..	o	A G	A G	A G	A G	A G	o	A G	A C	o	o	G T P	±
B. grünthali (Castellani)	+	A G	A G	A G	A G		o	o	A C	o	o	G T	+
B. entericus (Castellani)	o	A G	A G	A G	A G		A G	o	o	o	o	G T	o
B. para-entericus (Castellani) ..	+	A G	A G	A G	A G		A G	A G	A	o	o	G T	+
B. ceylonensis α (Castellani) ..	o	o	A	o	o		o	o	A C	o	o	G T P	o

A = Acid. G = Gas. C = Clot. A ALK } = Acid first, then alkaline. SL = Slight. G T = General turbidity.

P = Pellicle. + = Positive result (production of indol, or presence of motility, or liquefaction of gelatine or serum).

o = Negative result. ± = Sometimes positive, sometimes negative.

appear to be the dust. Flies, as has been experimentally demonstrated by one of us, are capable of carrying the bacilli, and ar therefore probably a prolific source of infection in tropical countries

It would, however, appear that the bacilli are capable of living in the alimentary canal without causing the symptoms of the disease until the vitality of the host is lowered by some agency such as a chill, an attack of diarrhœa, or some intercurrent disorder when they are capable of producing their ill-effects.

Pathology.—The bacilli taken into the body with food and drink pass to the intestine, in which they grow and multiply, and along the whole length of which they can be found. The researches of Flexner and Sweet have proved that the bacilli can abound in the small intestine, where no pathological lesion may be found. In the bowel they give rise to the toxins, of which two are known—one which acts upon the lower bowel, and the other on the nervous system. Both these toxins are absorbed into the blood, but the first, being excreted by the large bowel, causes the lesions well known to be associated with dysentery, and explains the localization of these lesions. In the process of excretion this toxin first causes an exudation of lymph into submucosa, and later into the mucosa. This lymph coagulates, and is invaded by a cellular exudate, and in due course the glands and the tissue of the mucosa and the muscularis mucosæ are destroyed by coagulative necrosis, with thrombosis of the vessels. This fibrinous or diphtheroid membrane is at first most marked on the summits of the ridges, and may not be found at the bottom between the ridges. It contains large numbers of micro-organisms of varying characters, while the depths of the submucosa may reveal accumulations of leucocytes, and the peritoneal coat may be œdematous. The micro-organisms destroy the fibrinous false membrane, which may separate off in flakes, thus causing ulcers, which are at first superficial, but later become deep and extensive. After treatment these ulcers heal with the formation of connective tissue, thus producing a scar in the mucous membrane, which in due course becomes pigmented from the sulphuretted hydrogen of the bowel acting on the iron of the blood. The other toxin may attack the nervous system, causing peripheral neuritis.

Very rarely do the bacilli enter the blood-stream and cause a true septicæmia, though such cases have been recorded by Rosenthal and Markwald, the latter observer stating that he found the bacilli in the blood and intestinal contents of a fœtus which had been prematurely expelled from the uterus of a mother who was suffering from bacillary dysentery.

Morbid Anatomy.—On opening the abdomen, the peritoneum is found in general to be normal, but the bloodvessels of the large bowel are seen to be injected, and the mesocolons may be infiltrated with lymph, or firm and fibrinous. There may be adhesions of the sigmoid colon to the omentum, pelvis, bladder, or small intestines, while the splenic flexure may be adherent to the spleen and surrounding parts, and the hepatic flexure to the liver. The cæcum may show adhesions to the omentum, and more rarely there may be pericæcal abscess. Signs of a general peritonitis may be met with, and will generally be associated with a gangrenous or perforated condition of the intestine.

The small bowel is usually normal, but may be hyperæmic or much more rarely, ecchymotic. The walls of the large intestine are usually considerably thickened and hyperæmic, and may at times be found to be gangrenous along a great or lesser extent of their course. On opening the large bowel, the mucosa will be seen to be covered with a coagulated exudate in the form of a false membrane, which is more evident on the summits of the folds and is especially well marked in the sigmoid colon, the cæcum, and the ampulla of the rectum. Around the areas covered by the false membrane the mucosa is seen to be hyperæmic and œdematous. As a rule, numerous ulcers are also to be seen, with clean surfaces, elevated edges, and a base formed by the submucosa. These ulcers may be very extensive, leading to the separation of large sloughs, or may extend deeply into the coats of the bowel, causing perforation and peritonitis, or in less serious cases to the exudation of much lymph into the peritoneum coat, which subsequently causes adhesions.

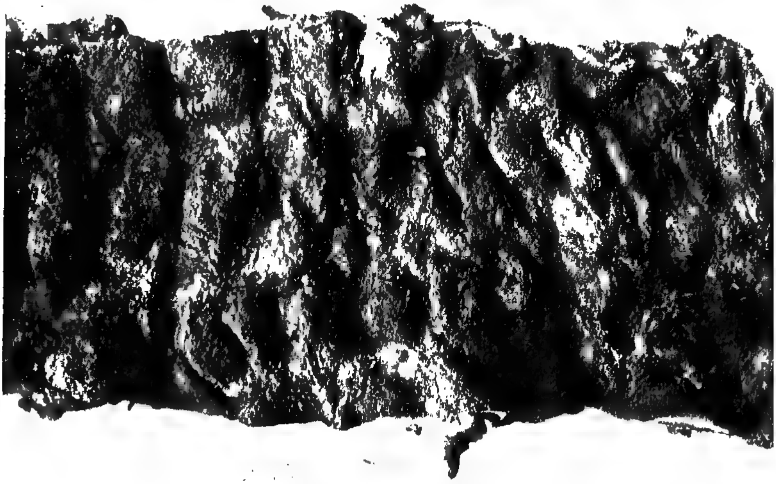

Fig. 338.—The Colon in a Case of Bacillary Dysentery.

In post-mortem examinations of cases which have died from some other complaint it is not unusual to find the intestines matted together in the pelvis, the omentum adherent to the colon, and the colon to the bladder, etc. On opening such a colon, it will be foun scarred by old dark-coloured cicatrices, indicating the position c the healed ulcers of a previous dysentery. More rarely the cicatrization may have proceeded to such an extent as to cause narrowing of the lumen of the gut, and still more rarely may the proces lead to abscess formation in the adherent omentum, the pus of thi abscess slowly working its way into the anterior abdominal wall and so to the exterior. The cæcum and other parts of the bowe may show polypi protruding from the mucous membrane, a condition often called ‘ colitis polyposa.’

In the epidemic diarrhœa of infants, the lesions which may be found are classifiable into hyperplasia of the agminated and solitary glands, superficial ulcers, lesions resembling those described above, or invisible lesions.

Microscopically, there is at first an exudation of fluid containing but few cells into the submucosa, while the mucosa is congested, but the glands are seen to be quite normal. A little later the exudate into the submucosa is seen to have formed fibrin, and the vessels of this coat are noted to be dilated, to contain numerous polymorphonuclear leucocytes, which may be seen undergoing diapedesis into the surrounding tissue. In this stage the exudate has also affected the mucosa, the glands and tissue of which may be seen to be undergoing coagulative necrosis. In a still later stage nothing is to be seen of the mucosa, and in bad cases of the submucosa, except fibrinous exudate, mixed with cells and blood-vessels. Often, however, the submucosa shows dense collections of leucocytes. Where ulcers occur the amount of exudate covering the muscular coat may be thin, while in other places it may be thick. The peritoneum is also generally infiltrated by a coagulated exudate.

Symptomatology.—The different appearances presented by the bacillary dysenteries may be grouped into—

1. The acute type.
2. The gangrenous type.
3. The entero-dysenteric type.
4. The paradysenteric type.
5. Chronic dysentery.
6. Dysenteric diarrhœa.
7. Dysenteric infantile diarrhœa.

1. *Acute Bacterial Dysentery.*—The incubation varies from twenty-four hours to three or four days, and is not well known in natural infections. Usually after an incubation of a few days, during which the patient may not feel quite well, and may complain of constipation or diarrhœa, with loss of appetite and malaise, the disease begins with an attack of pain in the lower part of the abdomen, and an urgent desire to defæcate, which results in the passage of perhaps an ordinary formed fæculent motion, which temporarily relieves the pain. Soon, however, another attack of pain is felt,

generally in the region of the umbilicus, from which it radiates to any part of the large intestine, and this is again associated with a desire to defæcate and the passage of a motion which is composed of fæcal matter, but may now be soft. The pain increases, and the desire to defæcate becomes more and more frequent, until almost constantly present, while any nourishment, however bland and unirritating, at once produces a desire to defæcate. After a time the patient sits almost continuously upon the commode, straining violently, and passing at first motions of fæculent matter mixed with blood and mucus, and then blood and mucus mixed with a little fæculent matter, and finally nothing but a little blood and mucus. As a result of the straining and the passage of numerous motions, the anus becomes inflamed and very painful, and prolapse of the bowel is not uncommon, and adds greatly to the distress of the patient. The urine diminishes in quantity, and therefore may show an increased quantity of urea, and at times may contain a trace of albumin. Pain is often complained of in the region of the bladder during and after straining at the commode. In slight cases the number of motions may be only about one every hour, but in more severe cases they number from fifty upwards, until they are passed almost continuously. This constant pain and desire to defæcate naturally weakens and exhausts the patient very quickly, for it prevents sleep and rest.

In ordinary cases the tongue is moist and coated with a white fur, and usually the patient is thirsty, but not markedly so, except in bad cases. Nausea is often present, and there is no desire for food, which is badly digested, and is often associated with epigastric pain. Vomiting occurs, but is relatively unusual in cases which are taken in hand early and properly treated. The abdomen soon becomes sunken and tender, especially along the course of the large bowel, but this tenderness may be restricted to certain areas only of that bowel. On careful palpation the thickened bowel may at times be felt, but usually it is too tender to allow such manipulation. With the numerous motions, it may be imagined that constipation would not occur; but this is not so, for the disease may be limited to the lower bowel, and as it is the involvement of the rectum which causes the tenesmus and constant desire to defæcate, fæces may be accumulating in the higher region of the large bowel —a condition which may be recognized by the distension. Shiga, indeed, describes an ascending variety of acute dysentery, which, beginning in the rectum, spreads upwards along the large bowel, as well as a descending variety, which usually starts in the small intestine. The typical motions are composed of blood and mucus only, but in bad cases they may consist of a reddish albuminous fluid containing white shreds. The typical dysenteric motions have no fæcal smell, and microscopically show numerous micro-organisms, blood, pus, and epithelial débris and cells. Usually there is some fever, ranging from 99° to 103° F. The pulse is quickened, and in bad cases may be not merely rapid, but irregular, when the heart will be found to be dilated, and perhaps hæmic murmurs may be heard; but these symptoms are unusual, except in grave cases. The blood usually shows a diminution in the red cells, and a slight polymorphonuclear leucocytosis. The lungs are usually normal. Delirium is unusual.

If the patient is to die, the motions assume the serous character mentioned above, the pulse becomes rapid and irregular, the temperature drops to subnormal, the motions diminish in number, hiccough appears, and exhaustion ushers in death generally during the second or third week.

If the patient is to recover, the motions become more fæculent, and the blood and mucus generally disappear, while the pain and tenesmus subside, the pulse returns to normal, the tongue cleans, and convalescence begins about the end of one week in mild, or of one month in more severe cases.

2. *Gangrenous Dysentery.*—This most severe type of the disease may begin insidiously with some slight fæculent diarrhœa, which may not attract attention until suddenly the patient becomes collapsed, and dies within a few hours without the passage of the typical motions. Thus a prisoner may stand in the dock throughout the whole day, and then die in the night from gangrenous dysentery, while his sudden death may awake suspicions of suicide.

The more usual history is that, during an attack of acute dysentery, the abdominal pain and tenesmus become very severe, while the motions alter their characters, becoming exceedingly offensive, and containing gangrenous sloughs composed of the mucosa and the submucosa. These sloughs may be small or large, and even at times may be tubular. The motions are now exceedingly numerous, and sometimes hæmorrhage *per anum* may take place. The patient becomes extremely exhausted, the pulse small and frequent, the temperature falls to subnormal, and the extremities become cold up to the knees and elbows, while the motions are passed involuntarily, and death takes place in some two or three days from exhaustion. Recovery from an attack of gangrenous dysentery is extremely unusual, but when it does occur the pulse slows, the temperature rises, the motions become fæculent again, and the urine, which has been suppressed, reappears.

3. *Entero-Dysentery.*—This variety begins with one or more rigors, and a rise of temperature to 103° F. or more. The temperature keeps high, assuming either a continuous or a high remittent type, and is associated with a dry tongue, and a mouth covered with sordes, fœtid breath, headache, malaise, pains in various parts of the body, marked epigastric disturbance, and often with ecchymoses under the skin in various parts of the body. The characteristic signs of abdominal pain and tenesmus are absent, and the motions, though containing blood and mucus, are mixed with considerable quantities of fæculent matter. The mind is clouded, the patient becoming very stupid, sleepless, and at times delirious. Abscesses may now appear in varying parts of the body, but

especially in the parotid or the ischio-rectal fossæ, while carbuncles, bedsores, and peritonitis may also occur. Death usually ensues after a few days' illness from exhaustion, toxæmia, or hyperpyrexia.

4. *Paradysentery.*—The incubation of this form of dysentery is not known, but is probably longer than in the acute dysentery, and may perhaps be about a week. The onset is usually sudden, beginning with pain in the lower part of the abdomen, generally radiating from the umbilicus to the sigmoid colon. At first there is merely diarrhœa, but this is soon replaced by motions containing only blood and mucus. The number of the motions, however, is relatively few, and the blood and mucus may only be present for a short time, while the pain and tenesmus is but slight. The temperature is usually normal, though it may be raised at first, while the tongue, though coated, is always moist. Paradysentery, in fact, is clinically a very mild attack of acute dysentery, and in Ceylon is generally due to *B. paradysenteriæ,* which is characterized by producing a permanent acid reaction in milk, while all the other bacilli render milk alkaline in a few days, after an initial acidity.

5. *Chronic Bacterial Dysentery.*—Chronic dysentery appears after an attack of acute dysentery which has apparently been cured, but in which, after a period of quiescence, diarrhœa appears. About five or six motions, composed of watery, evil-smelling fæculent matter, are passed *per diem*, and may at times contain blood and mucus, or simply mucus. After a time these symptoms disappear, and the motions become normal, or there may be slight constipation. In due course, however, the diarrhœa returns, and these exacerbations recur for months and years, and seriously affect the patient's general health. The appetite becomes bad ; the tongue red and smooth, or flabby and coated ; digestion is impaired, and fermentative changes cause the bowels to be distended with gas ; while hæmorrhage, slight or severe, may take place from the nose or under the skin. Profuse sweats may occur at night, and tend to exhaust the patient. Recovery may take place spontaneously, or after treatment, or the diarrhœa, continuing fitfully, may gradually wear out the patient, who may die of exhaustion or some intercurrent disease. Some authorities, with whom we do not agree, believe that chronic dysentery may become sprue.

6. *Dysenteric Diarrhœa.*—The term ' dysenteric diarrhœa ' may be applied to the non-bloody diarrhœa of chronic dysentery, and to those cases of diarrhœa which occur during an epidemic of dysentery, and in which the bacillus is either proved to be present in the motions, or the patient's blood agglutinates in high dilution one of the dysenteric bacilli. The attack may in no way differ from an ordinary attack of diarrhœa due to other causes, but is apt to recur and to turn into chronic dysentery.

7. *Dysenteric Infantile Diarrhœa.*—Diarrhœa is an extremely common disease among infants in the tropics, but has not yet received the attention which it has in the United States, in Europe, and in Japan, where it is called ' ekiri.' It is believed to be due to Flexner's

bacillus, or more rarely to Shiga-Kruse's bacillus; while the symptoms resemble entero-dysentery, being characterized by beginning with vomiting, and a rise of temperature from 103° to 104° F., a dry mouth, coated tongue, distended and tender abdomen, and the passage of motions containing fæculent matter, often green in colour, generally mixed with blood and mucus. The fever is of the remittent type, and as the disease progresses the child wastes, and may become convulsed or comatose and die, or may drag on for weeks, with repeated attacks of diarrhœa, and finally die from exhaustion. If recovery is to take place, the temperature declines, and the diarrhœa ceases, but the child is left in a pale and emaciated condition, from which it takes months to recover.

Complications.—Peripheral neuritis is not uncommonly met with, generally in a mild form, and often confined to one nerve. Arthritis is also not uncommon, while inflammation of the tendon-sheaths may also take place. In entero-dysentery parotid buboes are not uncommon, while abscesses in other parts of the body and peritonitis may develop. In gangrenous dysentery hæmorrhage may be a serious complication. Typhoid fever may occur at the same time as a dysenteric attack, and is a serious complication. We have met with several cases of appendicitis developing in people convalescent from dysentery.

Sequelæ.—One of the most important sequels of dysentery, to which Cantlie has recently drawn attention, is stenosis of the large bowel, and more particularly of the sigmoid flexure, due to cicatricial contraction of the healing ulcers. The symptoms are the onset of an insidious constipation, associated in due course with a sensation of distension in the abdomen, loss of appetite, and nausea. The constipation is apt to alternate with attacks of diarrhœa. In due course the constipation becomes severe, and is accompanied with recurrent attacks of colic, in which the pain may be localized or radiating, and sooner or later vomiting occurs. On inspecting the abdomen a swollen region may be observed, and the attacks of colic may be seen to be associated with visible peristaltic movements, while more or less meteorism occurs. Succussion sounds may be heard over the dilated bowel. This condition is serious, and must be energetically treated.

According to some authors, ' sprue ' is a sequel to dysentery, and we have, in fact, seen several cases of sprue developing in patients who had been suffering from chronic dysentery. We believe, however, the two diseases to be of quite different ætiology.

Diagnosis.—The diagnosis of bacillary dysentery has to be made with special reference to pseudo-dysentery and amœbic dysentery, especially when there is blood and mucus in the motions, and from the various forms of diarrhœa when these signs are absent.

With regard to pseudo-dysentery, cancer and syphilis of the rectum and inflamed hæmorrhoids may give rise to tenesmus and the passage of blood and mucus, but can be differentiated by the history and by an examination of the rectum. Cancer of the colon and intussusception may also cause the passage of blood, with or without mucus and with or without tenesmus, but the history and a careful abdominal examination, together with the discovery of a localized swelling, should serve to distinguish these affections. Parametritis on the left side may cause diarrhœa, and more rarely the passage of blood and mucus, but the absence of tenesmus, the presence of pain more at the side of the uterus than in the sigmoid colon, should indicate the necessity of an examination *per vaginam* or *per rectum*, when the nature of the case will be cleared up. A careful examination of the fæces should exclude such causes as fish-bones injuring the rectum. Mercurial poisoning can be distinguished by the history, the presence of salivation, etc.

The diagnosis from entamœbic, balantidic, and the other dysenteries of animal origin can only be made by the careful microscopical examination of the fæces, when the absence of these parasites will be made certain.

Positive diagnosis can, however, only be made by a bacteriological examination of the fæces and the determination of the specific bacillus. Agglutination tests with the patient's blood are not of much use in acute cases.

For the bacteriological diagnosis a shred of mucus or pus is smeared over a plate of MacConkey's bile—salt-lactose-neutral red-agar, by means of a bent glass rod or Kruse's platinum pencil.

Two more plates of the same medium are prepared in a similar manner without recharging the rod or pencil.

Any white colonies which develop are further investigated as to their sugar reactions, and by using the agglutination and absorption methods.

Prognosis.—In paradysentery and the milder forms of acute dysentery the prognosis is good, recovery being the rule, but the death-rate of severe acute dysentery is high, while the prognosis in gangrenous dysentery is very bad. As an average, the mortality of the various forms may perhaps range from 12 to 25 per cent., for there is no doubt that in Ceylon and other tropical countries dysentery is a more potent factor in the death-rate than malaria, though the latter may cause more illness.

The site of the disease is also a factor in determining the prognosis, being as a rule better if it is situate low down, and worse if high up in the bowel. According to Kruse, Shiga, Duval, Dopter, and our own experience, early serum treatment lessens the mortality considerably, and therefore improves the prognosis.

As regards age and sex, the prognosis is better for adults than for children, and for men rather than for women. Relatively, the European or new-comer into the tropics suffers more severely than the native resident race, but this racial difference is merely relative.

Treatment.—In all cases, however mild, the patient should be kept at rest in bed, and the urine-bottle and bed-pan must be used. The latter should preferably be slightly warmed before being used, especially in cool climates. Damp cotton-wool should be substituted for sanitary paper, in order to prevent irritation of the region of the anus.

All motions should be disinfected, after having been seen by the physician, with Jeyes' fluid or carbolic acid, and they should also be protected from flies. It is, however, most necessary that the motions should be saved for the physician to see, because they are extremely important in judging the progress of the case.

In **very mild cases** the bowels should be cleansed by an initial dose of one tablespoonful of castor oil, which may be administered in neat brandy, with or without a few drops of liquor opii sedativus or tincture of opium, and this should be followed a few hours later by the administration of astringents, such as bismuth salicylate 5 grains, and salol 5 grains, made into cachets, and taken every two or four hours at first, and less frequently when the character of the motions improves. In these mild cases tenesmus rarely requires any special treatment, and rectal injections are well borne, and may be administered twice daily, though in most cases they are unnecessary. These injections should consist of either boric acid (1 in 100), which is probably the best, salicylic acid (1 in 500), tannic acid (1 in 500), normal saline solution, or borax and bicarbonate of soda (5 grains of each to the ounce). In administering these enemata, the patient should lie on the left side, with the buttocks elevated on a pillow and the head placed low. A soft rectal tube should be smeared with vaseline and passed as high up the bowel as possible. Two pints of the enema are now run in by gravity from a glass irrigation vessel, and should be warmed to a temperature of about 99° to 100° F. The enema should be retained as long as possible. This treatment, with an appropriate diet, soon gives relief, the pain disappearing, the motions becoming fæculent. During convalescence a tonic of hydrochloric acid, cinchona bark, and gentian is found to be very serviceable.

In **severe cases** the serum treatment should be used as soon as possible, though at times it is useful to precede it with a dose of castor oil or salts. Kruse's serum, Shiga's serum, the Lister Institute serum (Todd), and that of the Pasteur Institute (Vaillart and Dopter) are all good. A polyvalent serum, such as that of Shiga, is preferable in those cases in which a complete ætiological diagnosis of the malady cannot be made.

The serum, in our experience, should be given in large doses; thus that from the Pasteur Institute and the Lister Institute should be given in 20 c.c. doses twice daily, and in very severe cases four times daily. The injection should be made under the skin of the abdomen or flank, using the ordinary aseptic precautions. These injections, as a rule, need not be continued after the second or third day. They may be followed by urticarial-like eruptions and pains in the joints. Calcium chloride in doses of gr. xv. to xxx. may be administered if these symptoms are severe. When the blood and mucus have disappeared from the stools, salol (gr. x. every four hours) or the ordinary astringents, such as bismuth, subnitrate or tannalbin (gr. x. to xv. every two hours), should be prescribed.

Shiga's rules for the administration of the polyvalent serum are:

I. In mild cases inject one dose of 10 c.c.
II. In cases of medium severity inject two doses of 10 c.c. at intervals of six hours.
III. In severe cases inject 10 c.c. twice a day at intervals of six hours for two or three consecutive days.

The serum has a marked effect upon the disease, hastening the cure, ameliorating the symptoms, and reducing the mortality.

When the serum treatment cannot be carried out, the *saline treatment* is, in our experience, the most useful. Two drachms of magnesium sulphate and 2 drachms of sodium sulphate, dissolved in an ounce of water, should be administered, and then 1 drachm of each should be given every hour or every two hours until the motions become fæculent, and then every three or four hours for another day.

There is generally considerable pain in these more acute cases, and therefore a fomentation sprinkled with laudanum should be applied to the abdomen, and the tenesmus should be relieved by suppositories of morphia or of cocaine. If these remedies fail, then hypodermic injections of morphia or opium (gr. ½) by the mouth must be given, for it is a most important factor in the treatment that the patient should not suffer more than can possibly be avoided from this distressing symptom. If prolapse of the anus or rectum occurs, it is important that this should be reduced and relieved by an astringent ointment, such as hazeline or gall and opium.

Rectal injections may be given, as described above, but in sensitive cases it is as well to pass in a second tube alongside the enema-tube, so that, instead of the inflamed bowel being distended by the injection, it may be simply washed by the irrigation of the boric lotion.

During the treatment of the severe acute forms a great danger is to stop the saline treatment too quickly, and to allow constipation to occur, by which is meant that, though the patient may be having fifty to a hundred motions *per diem*, still, fæculent matter is being retained. On the other hand, there is danger in continuing the saline treatment too long, for in our experience this should be stopped on the third day if there is no improvement, and also when the motions become serous.

After the acute stage is over it may be found useful to employ some astringent drugs, such as tanningen, in 5-grain doses, or tannalbin, 15 grains every two hours, or bismuth subnitrate (gr. x.) and salol (gr. x.) every two hours, administered in cachets or as enemata of boracic and tannic acid *per rectum*.

If there is a tendency to chronicity, fresh Bael fruit may be given. It must, however, be both fresh and ripe, and should be prepared by being boiled, and then shredded with a fork into warm milk, pressed and strained, and then a little sugar added. A tumblerful of the milk extract of Bael fruit may be taken twice daily.

Tincture of *Mansonia ovata* in 1-drachm doses is also recommended. Other remedies resembling the above are the roots of *Pelargonium tuberosa* and *P. flabellifolium.*

With regard to individual symptoms, *collapse* should be treated by the hypodermic injection of saline, *hæmorrhage* by ice-bags to the abdomen, and iced enemata.

Very severe cases, involving the whole of the large bowel, and gangrenous cases must be treated by appendicostomy and washing out of the bowel.

The simple operation is performed as follows : The patient is placed under chloroform, after the usual antiseptic preparation of the area of the operation. An incision of about 3 inches in length is made in the usual site for the operation of appendectomy, and, the layers of the abdominal wall having been incised, the peritoneum is carefully opened, and the appendix is searched for and brought forward into the wound, so that about 1 inch protrudes. Here it is fixed by four stitches to the muscles. The wound is now closed, the appendix being fixed to the skin by a couple of stitches. The wound is now dressed aseptically with a thin layer of wool and covered with collodion. The tip of the appendix is now removed, and a No. 8 or No. 6 catheter inserted. The wound is now dressed antiseptically and left for twenty-four hours, at the end of which time a large tube is placed in the rectum, and the whole bowel is irrigated with 1 per cent. solution of bicarbonate of soda to remove the mucus, and then with a boracic acid lotion, 1 drachm to the pint. This is repeated daily, but if the case tends to become chronic a solution of silver nitrate (20 to 40 grains to the pint) is used.

When the cure is effected, the small wound is easily closed.

Other methods of treatment include the calomel treatment much praised by Scheube and Kartulis, and begun long ago by the Indian physicians, and among the various forms in which it has been applied, Twining's pill of calomel, blue pill, and ipecacuanha used to be very celebrated. Plehn recommends that, after a preliminary dose of castor oil, ½ grain of calomel be administered hourly until twelve doses have been taken during the day. The treatment is discontinued during the night, and repeated in the same manner during the second and third days, after which bismuth subnitrate is given in 6-grain doses hourly during the day for a long period of time.

Yellow santonin, 10·3 grammes in 8 grammes of olive oil, administered three times a day, has been recommended by Drake. Musgrave recommends that acetozone (strength 1 in 5,000 ; aerated, if necessary) should be freely drunk, so as to prevent fermentation in the stomach and bowels. In all cases a mouth-wash—*e.g.*, glyco-thymoline—should be ordered. During convalescence the great point is to prevent chills and indiscretions in diet, which may induce attacks of diarrhœa. Turpentine, especially in combination with castor oil, has been recommended by some.

The sour-milk treatment may be tried with sauerin, lactobacillin, fermenlactyn, or any other preparation on the market, or by using the ferment as prepared by the natives of the country.

Constipation is counteracted by small doses of castor oil, Carlsbad salts, Hunyadi Janos, Apenta water, or enemata, but if of a marked nature should arouse suspicions of stenosis, especially if the ordinary laxative remedies do not ameliorate the condition. Under these circumstances sigmoidoscopy should be performed, and the stricture dilated by bougies or catheters.

Treatment of Dysenteric Infantile Diarrhœa.—The treatment of infantile diarrhœa and of dysentery in children is best conducted by administering a small dose of castor oil (ʒi. to ʒii.), followed by calomel (gr. $\frac{1}{6}$), or grey powder (gr. $\frac{1}{4}$) every hour until six doses are given in a child of two years of age. The dosage may be decreased or increased, according to age. Afterwards astringents such as tannigen (gr. iii.) or tannalbin (gr. v.) may be given every two to four hours.

In severe cases, due to the Shiga-Kruse or the Flexner bacillus, serum treatment is the best, 5 to 10 c.c. being injected twice daily.

The diet should be altered from milk to albumin-water, whey, diluted meat-juice, or clear soup.

Pain must be combated by hot fomentations, and convulsions by bromides given in gr. xv. as enemata, or in small doses by the mouth in albumin-water. Chloroform may require to be administered, while some authors recommend minute doses of morphia.

Treatment of Chronic Dysentery.—The treatment of chronic dysentery varies, for sometimes the malady is easily amenable to the treatment laid down for mild cases of acute dysentery, while at other times many remedies may be tried without success. Tannigen in 3 to 8 grain, or tannalbin in 8 to 15 grain doses, in cachets, may be tried three to six times a day. In old-standing cases pilula plumbi cum opio should be given twice a day. Serum treatment should also be tried during the exacerbations, as indicated above. Bael fruit, the rind of the mangosteen, simaruba bark, etc., are all useful in this condition, and the lavage treatment is more useful than in acute cases. Rectal irrigations should always begin with 2 pints of 1 per cent. solution of carbonate of soda to remove the adherent mucus, and then the medicated enema may be administered, and may consist of boracic acid (1 per cent.), followed by an enema containing bismuth subnitrate and sodium salicylate suspended in a pint or less of mucilage, silver nitrate ($\frac{1}{2}$ to 1 grain to the ounce), copper sulphate (2 grains, with 5 minims of tincture of opium to the ounce of water), tannin (0·25 to 0·5 per cent.), resorcin (1 to 2 per cent.), creolin (1 drachm to the pint), lysol (1 per cent.), or formalin (1 in 5,000), may all be used. Silver nitrate, however, gives the best results. Perchloride of mercury should not be used as a rectal enema, as it is dangerous, and may increase the symptoms instead of diminishing them. In chronic or subacute obstinate cases the *vaccine treatment* first introduced for dysentery by Castellani and Greig may be tried, using vaccines prepared from the dysenteric bacilli isolated from the stools of the patient. Forster has tried this treatment also in acute cases. In our experience it gives good results in several cases of the chronic type, but in acute dysentery is much inferior to the serum and saline treatment.

If all these methods of treatment fail, appendicostomy should be tried.

Diet.—There is no point in the treatment of dysentery of greater importance than the diet. The bowel requires physiological rest, and, therefore, in the very severe cases the diet must be restricted to albumin-water and whey, and brandy given only if absolutely necessary.

In milder cases the diet should consist of milk, which must be diluted with Perrier, soda, Vichy, or barley water, or may be mixed with powders of sodium bicarbonate (gr. vi.), potassium bicarbonate (gr. vi.), sodium chloride (gr. iii.), or sodium citrate (gr. xl.), to the pint of milk, and less in proportion. Arrowroot made with water or milk, at first thin and later thick and flavoured with a little brandy, is most useful. Benger's food and Horlick's malted milk are also useful. Strong meat-essences and alcohol should be avoided.

In all severe cases the food must be given in small quantities every two hours, about 4 ounces at a time, and must be taken very slowly, and should be neither very warm nor cold. In chronic dysentery this milk diet is of the greatest importance, and should, as already stated, be supplemented by the sour-milk treatment.

When convalescence begins, chicken-broth and milk-puddings may be added to the diet, and then lightly-boiled eggs and toast; then chicken cream, and fish; but for a long time only white flesh should be allowed, and not much of this, for the diet should for several weeks consist largely of milk foods. Of especial importance in convalescence is the chewing of the food, and care must be taken not merely that the teeth are in good order, but that the patient is directed not to swallow any tough or very fibrous piece of food. Fruits must be avoided for a long time.

Prophylaxis.—The prophylaxis consists in drinking only filtered and boiled water, and using the same for cleaning the teeth, in avoiding salads and fresh vegetables and unripe fruit, and in carefully washing the exterior of any fruit in which this is likely to be eaten.

Various methods of vaccination have been tried by Kruse, Shiga, and Castellani, with apparently fairly good results. Castellani's method consists in giving first an inoculation of ½ c.c. of dead vaccine (peptone-water cultures heated to 55° C. for one hour), followed after a week by a second inoculation of 1 c.c. of live vaccine (peptone-water cultures of a non-virulent strain heated to 50° C. for one hour). Broth cultures should not be used, as they give rise to very severe local and general reactions.

With regard to public prophylaxis, a modern method of collecting and disposing of the sewage of towns is necessary everywhere in order to prevent the disease from spreading, and there is no doubt that for this purpose the best method for tropical towns is the Shone or pneumatic system, as introduced into Rangoon, Bombay, and Karachi.

Good scavenging and strict hygienic laws are necessary to prevent the breeding of flies, and if an epidemic of dysentery occurs a special crusade against the common house-fly should at once be undertaken, as has been done for other reasons in Liverpool and elsewhere.

Dust should be diminished in the warm dry weather by the efficient watering and brushing of the roads of towns, and in this water some cheap disinfectant should be used, especially for the more important streets.

The drinking-water of all large towns should be filtered, though it must be admitted that this alone is not a sufficient safeguard against a water-borne epidemic.

C. PSEUDO-DYSENTERIES.

Definition.—Pseudo-dysenteries are diseases other than those defined above, which give rise to diarrhœa, with the passage of blood and mucus in the motions, and are sometimes associated with abdominal pain and tenesmus, and may readily, on superficial examination, be mistaken for true dysentery. It should, however, be noted that the term 'pseudo-dysentery' has been used by Kruse to signify a form of bacterial dysentery commonly found among inmates of lunatic asylums, and later to denote every variety of the disease not caused by the Shiga-Kruse bacillus.

Ætiology.—The most common causes of the pseudo-dysenteries are cancers of the intestine, especially of the rectum, inflamed piles, gummata in the rectum, cancers of the large bowel other than the rectum, and intussusception. The native habit of eating the small bones of fish along with the flesh is apt to cause irritation of the rectum and a pseudo-dysenteric attack. Inflammations of he broad ligament, especially on the left side, are apt to be confused with a mild attack of dysentery. Poisons, such as mercury, ptomaines, ricin, abrin, etc., may also produce symptoms, resembling dysenteric attacks.*

Diagnosis.—The diagnosis of these various conditions has already been discussed in the Diagnosis of Bacillary Dysentery, and need not be repeated.

Treatment.—The treatment must be adapted to the specific complaint, while the bowel symptoms may be relieved as indicated under the treatment of Bacillary Dysentery.

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* Prout has described a form of dysentery in the Gambia due to drinking water containing the excreta of locusts.

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CHAPTER XLVI

DISEASES OF THE ALIMENTARY CANAL (*concluded*)—INTESTINAL BILHARZIOSIS AND EPIDEMIC GANGRENOUS RECTITIS

Intestinal bilharziosis—Epidemic gangrenous rectitis—References.

INTESTINAL BILHARZIOSIS.

Synonyms.—Rectal Bilharziosis, Hepatic Bilharziosis.

Definition.—Intestinal Bilharziosis is infection with *Schistosomum mansoni* Sambon 1907, the eggs of which invade and irritate the intestines and the liver, and cause inflammation.

History.—It has long been known that the eggs found in cases of intestinal, rectal, and hepatic bilharziosis are laterally spined, as Bilharz pointed out long ago in 1851 ; and Sonsino once stated that the two worms must belong to different species, but this statement did not attract attention. In 1903 Manson first suggested that these eggs might belong to a new species of *Schistosomum*, and in 1907 Sambon first showed that a separate species really did exist, calling this *S. mansoni*, in which he has been supported by Holcomb and others, though opposed by the great authority of Looss.

Very recently a description of the adult worms has been given by Da Silva confirming the differentiation of the two species.

Climatology.—As far as is known at present, the disease exists in Egypt, Central Africa and South Africa, Central and South America, and the West Indies.

Pathology.—The worms live in the portal vein, but are especially attracted to the bowels, in the capillaries of which they lay their eggs, which burst those vessels, and escape into the mucosa, causing therein a dense cellular infiltration, which leads to a thickening of the coats of the bowel, and to the formation of papillomata, which may become detached and form ulcers. Dense fibrous infiltration of the peritoneum may also occur, and contain both eggs and worms. The mucosa of the bowel is protected by a quantity of mucus. In the rectum the mucous membrane is apt to become hypertrophied, and to grow, forming large polypoid masses, or adenomata, which may protrude through the anus. The ova may affect the subcutaneous tissue of the sacral and coccygeal regions, and cause dense cellular infiltrations, giving rise to fistulæ, which may spread and infect a large cutaneous area.

When the ova reach the liver by the blood-stream, they give rise to fibrous tissue formation or an abscess. Gall-stones may also form round the ova in the gall-bladder. The pancreas and spleen may also be infected, and the vulva and vagina.

The ova may also reach the lungs, causing a chronic interstitial pneumonia, and passing through these organs, may enter the heart and the general circulation.

Symptomatology.—The symptoms resemble those of chronic dysentery, consisting of pains in the abdomen and the passage of blood and mucus. The fæces contain the characteristic ova. Papillomatous growths may form in the rectum, and can be distinguished from piles by their large number. They may protrude from the anus, when the removal and microscopical examination of a small portion will clear up the diagnosis. Hard masses may be felt through the abdominal wall, signifying that a portion of the bowel and peritoneum have become infiltrated with fibrous tissue and eggs, and filled with papillomata. The liver and spleen may be enlarged. When the lower part of the rectum is involved, much agony from tenesmus and the passage of blood and mucus is experienced. If the patient removes from the endemic area, improvement will take place ; but if he remains, then no cure appears to be possible, and he dies sooner or later from exhaustion.

Complications.—A case may be complicated with urinary bilharziosis, agchylostomiasis, and other intestinal parasitic diseases.

Diagnosis.—The diagnosis must be made by finding the characteristic lateral spined eggs in the fæces.

Prognosis.—The prognosis is unfavourable. It must be noted, however, that in some cases the parasite does not give rise to any distinct pathological symptoms for a long time. One of us has observed in Uganda several natives with eggs of *S. mansoni* in their fæces, although they were apparently in good health. The stools, apart from the eggs of the worm, were normal.

Treatment.—But little can be done in the way of treatment. *Filix mas* may be administered with the purpose of eradicating the worms, and symptomatic treatment may be carried out as mentioned under Urinary Bilharziosis. Madden advises an enterotomy and a cleaning out of the bowel, when a tumour can be felt, and a Whitehead's operation may be done to relieve the rectal symptoms. Recently Vincent has suggested that large intestinal irrigations of a solution of sodium hypochlorite (8 to 10 per 1,000) should be given.

EPIDEMIC GANGRENOUS RECTITIS.

Under this term Eckers and Manson describe a disease which may start in the rectum or in the colon in animals and natives in British Guiana and Venezuela, and perhaps elsewhere. It is known in the former region as ‘caribi,’ and in the latter as ‘el becho.’ It is said to be very contagious, which is against the native theory that it is caused by eating unripe maize.

The disease begins as an itching about the anus, followed by symptoms of acute dysentery, which increase in severity until there is a constant discharge of blood-stained or greenish fœtid fluid. Prolapse and gangrene of the rectum may now occur, or convulsions may supervene, but in either case the patient dies.

Natives treat the disease by enemata of strong lemon-juice mixed with dilute rum, a dose of castor oil being given at the same time. Enemata and decoctions of *Spigelia anthelmintica* are also prescribed. In children a portion of a lemon is roasted and inserted *per anum.* According to local medical men this native treatment is more efficacious than boric-acid enemata.

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CHAPTER XLVII

DISEASES OF THE LIVER AND PANCREAS

General remarks—Tropical liver—Entamœbic abscess of the liver—Opisthorchiosis—Clonorchiosis—References.

GENERAL REMARKS

DISEASES of the liver and pancreas are of common occurrence in the tropics. The liver may be affected in the course of tropical fevers, especially in malaria and kala-azar, in the latter of which Rogers has described a special form of cirrhosis. The disease called 'infantile biliary cirrhosis of the liver, described by Ghose and Mackenzie as occurring in Calcutta and other parts of India in Hindu and Mohammedan children, appears to us to require reinvestigation, with a view to deciding whether it also is a variety of kala-azar. It is said to attack children under one year of age, and to be characterized by a low type of fever, associated with enlargement of the liver and spleen, jaundice, pale motions, dark urine, and sometimes vomiting of blood, œdema, and ascites, and ends fatally in three to eight months.

Similarly 'ponos,' a word which simply means pain, has been described as a disease of infants under one year of age in Spezzia and Hydra, characterized by irregular fever associated with painful enlargement of the liver and spleen, œdema and ascites and progressive emaciation. It may be complicated by dysentery, diarrhœa, etc., and usually ends fatally after a course varying from a few months to two years. It also requires reinvestigation with a view to deciding whether it also is kala-azar. Possibly it is identical with the infantile splenic anæmia met with in Italy, Sicily, and Tunis, and caused by *L. infantum* Nicolle.

Acute yellow atrophy of the liver is not as uncommon in Ceylon as in Europe, for, on an average, we have met with one or two cases per annum. It occurs in Ceylon more commonly in men than in women, but the cause appears to be quite obscure.

An extraordinary case of acute severe hepatitis and gastritis, which caused a considerable hæmorrhage to take place, filling all the small biliary ducts, the gall-bladder, the common bile-duct, the duodenum, jejunum, and ileum with blood, has been recorded by one of us in Ceylon. The inflammation occurred in a stomach which was altered by chronic atrophic gastritis. The hæmorrhage was caused by the blood passing from the damaged hepatic capillaries into the minute bile channels, and was due to the destruction of the walls of these capillaries and the liver cells. No definite cause could be found for this condition, which is decidedly rare.

Congestion and inflammation of the liver, together with abscess, are common in the tropics, and require special consideration.

Atrophic cirrhosis of the liver is very common in the tropics, and though generally there is a history of alcohol, still, this is by no means always so, and sometimes the cause is not evident. We believe that cirrhosis of the liver of malarial origin is much less frequent than is admitted by many authors. It will be shown presently that various parasites cause cirrhosis.

Primary cancer of the liver has been met with, but is very rare. On the other hand, secondary cancer is by no means rare. The only non-malignant growth which we have met with was an angioma.

The protozoal parasites which occur in the liver are *Entamœba histolytica*, the cause of liver abscess; *Leishmania donovani* and *L. infantum*, the causes of kala-azar and the infantile cirrhosis of the liver mentioned above; and the malarial parasites, as has already been noted. *Eimeria stiedæ* has not been found in the tropics in man.

With regard to the trematode parasites of the liver, *Fasciolopsis buski* (*rathouisi*) has been seen in a Chinese who showed obscure liver symptoms, and no doubt microscopical examination of the fæces would make diagnosis possible; but there is only one certain case, and the information regarding the symptoms is meagre. *Opisthorchis noverca* and *O. felineus* are the cause of opisthorchiosis, which will be considered later, as will clonorchiosis, caused by *Clonorchis sinensis* and *C. endemicus*. *Dicrocœlium lanceatum* is considered to be too small to cause any serious symptoms while living in the bile-ducts. *Schistosomum mansoni* and *S. japonicum* may both affect the liver.

With regard to tape-worms, *Tænia echinococcus* is not common, but we have met with one case of echinococcus in Ceylon, which was brought by a Boer prisoner, and Begbie has recorded another, not in the liver, but associated with the lung, in an old resident in Ceylon. One of us had recorded an invasion of the liver by Ascarides, and the formation of abscesses by the agency of these worms. We have also recorded *Porocephalus armillatus* in the liver.

Disease of the gall-bladder is not very common in the tropics, but we have met with acute and chronic inflammations. Gall-stones are often met with, probably as sequelæ to typhoid fever, but also arising from other causes. Suppuration of the bile-ducts ve have only seen once, and œdema of the wall of the gall-bladder ve have also only found once. Obstructive and catarrhal jaundice re met with fairly frequently in the tropics.

Rupture of the liver may take place as the result of traumatisms, nd recently Herzog has recorded this accident in a Filipino woman s the result of a native obstetrical practice, which consists of traction n a cloth wound round the abdomen. In this case the rupture ad been caused by the perforation of the tip of the eleventh rib nto the fatty liver.

In our experience, the pancreas is not infrequently found iseased. We have met with the following types of inflammation n Ceylon :

1. Acute hæmorrhagic pancreatitis.
2. Acute suppurative catarrh of the ducts.
3. Subacute pancreatitis.
4. Chronic pancreatitis.
    (1) Syphilitic in the fœtus.
    (2) In the adult.
        (*a*) Chronic interlobular pancreatitis.
        (*b*) Chronic interacinar pancreatitis.
        (*c*) Chronic interlobular and interacinar pancreatitis combined.

It should be remembered that the subtertian parasite is one of he causes of hæmorrhagic pancreatitis. In addition, we have seen ancer of the pancreas producing a blocking of the duct of Wirsung, nd leading to a ranula which contained many pancreatic calculi. Ve have once seen an ascaris in the duct of Wirsung associated ith a hyperæmic condition of the gland.

After this brief general statement, we must consider congestion f the liver, abscess of the liver, opisthorchiosis, and clonorchiosis.

TROPICAL LIVER.

Synonyms.—Congestion of the Liver, Hyperæmia of the Liver, dian Liver.

Definition.—Congestion of the liver is a hyperæmia brought out by many conditions, especially gastro-intestinal disorders.

Remarks.—There can be no doubt that the European is apt to t and drink more than is good for him on his first arrival in the opics, and that this is bound to lead to an increase of blood in e liver, which physiological condition may easily become a con-stion, with later blood stasis and diminution of the functional tivity of the organ.

Climatology.—Congestion of the liver is a cosmopolitan complaint, t is much more commonly met with in the tropics than in the mperate Zone.

Ætiology.—Congestion of the liver is brought about by indiscre-n in diet, such as too much, too rich, or too highly spiced foods, alcoholic excess, and by chills.

Pathology.—Post mortem the liver is found to be swollen, dark red in colour, and drips with blood when cut into. The cells are often laden with fat, and, in addition to the changes in the liver, there will be added the pathological changes which have caused the congestion, and which are generally to be found in the alimentary canal, as well as those which have caused the death of the patient.

Symptomatology.—The illness begins with frontal headache, malaise and loss of appetite, with nausea or sickness, and a bitter taste in the mouth on awakening in the morning. The tongue is coated, and there are the usual signs of dyspepsia, associated with constipation and the passage of pale-coloured motions. The liver is enlarged and tender, and usually there is a sense of weight in the right hypochondrium, and pain below the right scapula or in the right shoulder, and there may be slight signs of jaundice in the yellow conjunctiva and sallow skin. The urine may be diminished in quantity, high-coloured, and with high specific gravity, and loaded with uric acid and urates. The nervous system is also affected, and the patient is usually very cross and irritable. The temperature is generally normal, but sometimes it rises, and when above 100° F. it is usual to call the disease hepatitis, instead of congestion of the liver. The common non-febrile variety lasts from two to seven days, but is liable to recur.

Varieties.—Congestion of the liver may be acute when associated with some other disease, or chronic when due to gastro-intestinal disturbance.

Diagnosis.—The diagnosis is based on the painful enlargement of the liver, which, in the absence of other disease, is usually unaccompanied with marked rise of temperature.

Treatment.—In the acute attack it is as well to keep the patient in bed and begin the treatment with a dose of calomel (gr. ii. to gr. v.), followed a few hours later by a saline in the form of magnesium and sodium sulphates or Carlsbad salts. An effervescing mixture of ammonium carbonate and sodium bicarbonate, with citric acid, may be given every three hours, or a mixture containing ammonium chloride in some combination. At the same time hot fomentations or a thick coat of antiphlogistin may be applied to the region of the liver. The diet should consist of soups and milk, diluted with Vichy or barley water, and no alcohol in any form allowed.

When the condition has become chronic, the patient must be carefully dieted and placed upon a course of treatment with the above effervescing mixture and Vichy (Grande Grille), and when leave in Europe is available, should be sent to Vichy, Carlsbad, Harrogate, or Montecatini. He should avoid alcoholic stimulants and rich food of every description, and especially tinned food, and should restrict his diet to fowls, clear soups, fish, and well-cooked vegetables and milk, avoiding meat and curries.

Whenever the acute attack is over, the patient should be advised to take exercise daily—walking, riding, golf, or tennis, combined with the usual so-called liver exercises.

Prophylaxis.—Plain, simple, not highly spiced food should be taken, and such pernicious drinks as the heavy forms of beer, sherry, champagne, etc., should be avoided. If any form of alcohol is to be taken in the tropics, this should be Scotch whisky, well diluted, or light clarets, and then only in moderation. Chills must be avoided as carefully as possible, especially when there is a land wind, in the rains, and when changing from a warm to a cooler climate.

With regard to the cold bath, there is no doubt that the majority of people are unable to stand this in the tropics, and therefore it is better to use water with the chill removed.

Some persons are, however, distinctly benefited by a cold bath, and therefore individual peculiarities must be considered.

The most dangerous time for chills is in the night; therefore it is as well to sleep with some light blanket placed over the abdomen, and in flannel night attire. In the daytime a woollen undervest or cholera-belt may be worn. The clothes must be carefully changed whenever they become damp.

ENTAMŒBIC ABSCESS OF THE LIVER.

Synonyms.—Hepatic Abscess, Abscès du Foie, Tropischer Leberabszess, Epatite Suppurativa.

Definition.—Amœbic abscess of the liver is a suppurative hepatitis, caused by *Entamœba histolytica* (and perhaps other species of *Entamœbæ*), usually preceded by an attack of amœbic dysentery.

History.—Liver abscess was known to the ancients, and was operated upon as far back as the days of Hippocrates, while Galen recognized its connection with dysentery, and Morgagni studied its morbid anatomy. During the nineteenth century the disease was carefully studied by French surgeons, beginning with those of the army of occupation in Egypt, and also by the French colonial doctors and the Indian army surgeons. The discovery of *Entamœbæ* emphasized the connection between liver abscess and dysentery. Kruse and Pasquale were the first to regularly find amœbæ in the liver abscess, and to state that, apart from the amœbæ, the pus was sterile. Later researches have confirmed this discovery, and have demonstrated that the pus of a liver abscess does not contain bacteria in most cases—a fact which agrees with our experience—and that the true cause of the malady is *E. histolytica.*

Climatology.—Liver abscess is essentially a disease of the tropics and subtropical regions. It is very common in India and Indo-China, rather less so in Ceylon, Malaya, Java, Sumatra, and rare in Southern China. In Africa it is common in Egypt and North and West Africa (Gold Coast). In America it appears to be less commonly met with, being rare in the United States, West Indies, and British Guiana. It is also found, though rarely, in the Temperate Zone, in Spain, Italy, France, and even in such a northern country as England. There is no seasonal variation.

Ætiology.—The cause of the suppuration is *E. histolytica* Schaudinn, and perhaps other varieties of *Entamœbæ.* It is more common in Europeans than in natives, and more so in males than females, and is usually a disease of adults. The most important predisposing cause is perhaps alcohol.

Pathology.—The *Entamœbæ* pass from the bowel via the portal vein into the liver, where they produce coagulative necrosis of the liver cells, which become formless and break up into granular débris. This necrosis is thought to be brought about by means of toxins produced by the *Entamœbæ.* The necrosed area undergoes liquefaction and forms the abscess, the contents of which consist of débris, endothelial cells, mononuclear leucocytes (rarely polymorphonuclears), red corpuscles, hæmatoidin, cholesterin, and rarely Charcot-Leyden crystals. The pus is usually sterile, and as a rule does not contain amœbæ, which are in the marginal wall of the abscess, and may extend into the liver tissue for some distance from the focal lesion. After the abscess has been opened, amœbæ may be found in the pus. The process of repair has not been fully worked out, but it appears as though the granulation tissue formed new connective tissue, in which new bloodvessels and proliferating bile-ducts may be seen, indicating the processes which may lead to repair.

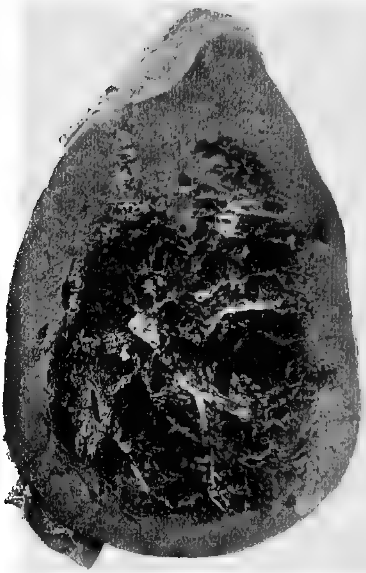
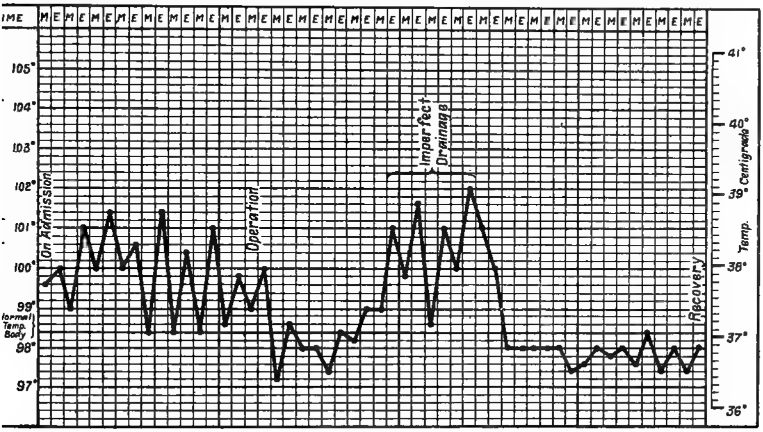


FIG. 339.—ENTAMŒBIC ABSCESS OF THE LIVER.

Usually there is only one abscess, but it is not uncommon to find two, and there may be more. The abscess is generally found in the posterior part of the upper portion of the right lobe. It is rounded in form, with walls composed of degenerated liver cells and granulation tissue. Its contents may be thick, creamy pus, but more usually it is yellowish or brown-coloured. On microscopical examination it consists largely of detritus, with a few degenerated liver and pus cells. The bacteria found in the pus, when it is not sterile, are streptococci, staphylococci, *B. coli communis*, and *B. pyocyaneus*, and occasionally some anaërobic germs. The abscess varies much in size, from a small hollow containing only 1 or 2 ounces up to a huge cavity with a couple of pints or more of pus, while even larger have been described. The size of the liver, apart from the abscess, also varies, being sometimes increased and sometimes diminished. Apart from the liver abscess, there are sually signs of old or recent dysentery in the colon, though these ay be absent. There may be abscesses in other parts of the body, it these are rare.

Symptomatology.—There is usually a history of a previous attack dysentery, but this may be wanting. The disease begins in-diously with signs of congestion of the liver and fever. This fever important, being irregular, sometimes remittent, sometimes termittent, sometimes with long apyrexial intervals.

The X rays may show that the movement of the diaphragm is iminished on the right side. This early stage, called by Rogers e 'presuppurative stage,' is of the utmost importance; for if it n be recognized and appropriate treatment applied, the disease ay be stopped in a certain number of cases. If, however, this is ot done, rigors may take place, and the fever usually becomes ore severe, and a typical hectic temperature with night-sweats ay ensue; while the patient complains of a dragging sensation on e right side, pain under the right shoulder-blade and in the right oulder. This latter is a referred pain, due to the fact that the renic nerve arises from the fourth cervical nerve-root, the fibres which supply the skin of the shoulder.



.G. 340.—THE TEMPERATURE-CHART OF A CASE OF ABSCESS OF THE LIVER.

A patient with an abscess of the liver often possesses a most pical facies. He lies on his back, with his legs drawn up; his face drawn, and of a pale yellow colour, and the ocular conjunctiva ssesses a peculiar bluey-whitish colour. It is said that sometimes e right pupil is dilated, but in our experience this is not a constant mptom. Generally he is emaciated, and deep inspiration is pain-l; hence the breathing is costal in character, and often there is a ght cough. The hands and feet are often cold and clammy to e touch.

On inspecting the abdomen and chest, the right hypochondrium will be noticed to be bulging, while the liver is enlarged and tender. On palpating the front of the abdomen, the right rectus muscle may be felt to become suddenly rigid—a most characteristic sign—while the left is not affected. On percussion the liver is found to be enlarged, and pain may be produced by pressure in the epigastrium or over an intercostal space. These painful spots are of importance in localizing the site of the abscess. On listening over the lower part of the chest, fine crepitations or friction sounds may be heard.

Usually liver abscess is accompanied by some anæmia and some increase in the number of the total leucocytes, but this appears to vary, being greater if the abscess is small and deeply seated, and less so if large and superficial. According to Rogers, the ratio of white to red corpuscles varies from 1 : 517 to 1 : 126. With regard to the differential count, the polymorphonuclear leucocytes are but slightly increased, but the lymphocytes are usually more than normal. Léger gives the differential count as being: polymorphonuclears, 79·67 per cent.; lymphocytes, 18·5 per cent.; mononuclears, 1·29 per cent.; and eosinophiles, 2·03 per cent., which closely agrees with Rogers' figures, which are: polymorphonuclears, 74 to 87 per cent.; lymphocytes, 7 to 22 per cent.; mononuclears, 3 to 7 per cent.; eosinophiles, 0 to 4 per cent. In some of our cases there was no polymorphonuclear leucocytosis, while on several occasions, even in non-malarial subjects, there was a relative large mononuclear increase. The number of sudanophile leucocytes tested according to the Cesaris-Demel method is often increased.

The urine is usually diminished, and its excretion is said to be altered, so that the greatest quantity is passed between 12 midnight and 12 noon, being especially increased in the early morning.

If the abscess is allowed to continue its own course, it may burst into the lung, causing signs of pleurisy and pneumonia, associated with the expectoration of characteristic brown or reddish-brown gummy, viscid, purulent matter; or into the stomach, when a similar material will be vomited; or into the bowel, when it will be passed *per anum*. It may also burst into the pericardium or the peritoneum, or into the vena cava, all of which cases are bound to end fatally. If it does not burst, the patient may die of exhaustion.

The duration of a liver abscess is very variable, being from a few weeks to several months, and even years.

Diagnosis.—The diagnostic points in abscess of the liver are: painful enlargement of the liver; the characteristic pain in the shoulder; the rigidity of the right rectus; the loss of movement in the right side of the diaphragm on radioscopy; and, above all, the discovery of the pus by exploratory puncture, as described below.

Pleurisy with effusion on the right side can be distinguished from liver abscess by the presence of Grocco's paravertebral triangle on the left side. Moreover, in pleuritic effusions the upper limit of the dulness is horizontal, while in liver abscess it is convex. Another diagnostic point to which Manson has drawn attention is that the enlarged liver gravitates with changes of position much more distinctly than pleural effusions. If the dulness in the mid-axillary line diminishes notably when the patient lies on his left side, the case is probably one of liver abscess. It is to be noted, however, that a right pleural effusion and a liver abscess may coexist. Pneumonia on the right side with congestion of the liver may also lead to difficulties, which must be met by careful physical examination and the microscopical and bacteriological examination of the sputum. Malarial fever can be diagnosed from the fever of hepatitis by examination of the blood and the presence of the enlarged spleen. In those cases of liver abscess in which fever is the only symptom the diagnosis may be extremely difficult, and may require all modern bacteriological methods to exclude Malta fever, malaria, septicæmia, and typhoid, etc. When in doubt, an exploratory puncture should always be made, for it can do no harm, and may relieve the congestion. When a long needle is introduced into a liver abscess, it moves regularly with respiration. Purulent cholecystitis in most cases gives no trouble on diagnosis, as the enlarged gall-bladder can be easily felt, and there is generally a history of hepatic colic.

Syphilitic gumma of the liver may show many symptoms in common with liver abscess, including the intermittent fever, as we have twice noted. The action of potassium iodide in full doses clears the diagnosis.

Cases of leukæmia, pseudo-leukæmia, and kala-azar have been mistaken for liver abscess, but in all these conditions the spleen is also greatly enlarged.

In this connection we may emphasize the necessity for the examination of the blood in order to exclude leukæmia, otherwise a fatal hæmorrhage may follow such a simple operation as puncture of the liver. Liver abscess is usually easily diagnosed from hydatid disease, but when purulent changes have taken place in the latter the diagnosis may be impossible, except by the history and the eosinophilia.

Prognosis.—If the abscess is left unoperated for a long time, the prognosis is very bad, as the danger of exhaustion and septic infection is great. If the abscess has burst into the lung, the prognosis is also bad, but better than if it had burst into the bowel. Since operative measures have come into more common use, the mortality has decreased, according to Dujardin Beaumetz, from 82 per cent. to 32 per cent.

Treatment.—If a case is suspected by the symptoms and blood-counts to be in the 'presuppurative stage,' ipecacuanha should be administered, and should be given with the precautions already mentioned under Amœbic Dysentery, and must be continued for several weeks after every sign of hepatitis has disappeared.

If, however, an abscess is believed to have formed, there should be no delay in making an exploratory puncture.

For this purpose a needle 3½ inches in length, but preferably not longer, because of the danger of injuring the vena cava, should be rendered sterile by boiling in plain water, but must not be dipped into an antiseptic lotion nor into spirit. This needle should be capable of being fitted on to a glass syringe or an aspirator.

The patient should be placed under chloroform, and all arrangements should be made so that an operation can be performed at once if necessary.

The needle should be driven into the liver in the region of any definite swelling or pain, or, failing these, through the eighth intercostal space in the anterior axillary line, about 1 or 1½ inches from the costal margin.

The direction of the needle should be inward, slightly upward and backward, because the usual site of an abscess is in the upper and back part of the right lobe.

Aspiration by the syringe or the aspirator may reveal pus, or may fail to do so, in which latter event the needle must be carefully and slowly withdrawn, and its contents ejected on to a clean white dish, to see if it is composed of the grumous material of liver abscess. The needle should now be driven into the liver in different places and directions until some six to twelve punctures have been made. There is no danger in this procedure if performed with reasonable care, and it may even benefit the patient by performing what has been termed ‘hepatic phlebotomy.’ When the abscess has been located, the needle should be left *in situ* as a guide, and one of two procedures may be carried out: A. Aspiration; B. Operation.

The operation should, however, be always performed if the abscess has already burst into the lungs, the peritoneal or pleural cavities.

A. ASPIRATION.—This is preferable if the abscess is small, and consists of evacuating its contents, and the repeated irrigation of the cavity with a solution of bi-hydrochloride of quinine (3 to 5 grains to the ounce) by means of Rogers' flexible sheathed aspiration cannula.

B. OPERATION.—An operation is necessary if the abscess is large, if the pus is not sterile, if the abscess has burst into the lungs or a serous cavity.

The site of the operation depends upon where the pus has been obtained. Two principal places may be mentioned: (1) through the thoracic wall; (2) through the abdominal wall below the ribs.

Giordano and others have recommended a laparotomy and the localization of the abscess by the hand prior to the actual operation for evacuation of the pus. This may be useful in certain cases when there are no signs indicating the position of the abscess.

1. *Operation through the Thoracic Wall.*—An incision should be made through the parietes, including the site of the puncture, through which pus was obtained. After the skin has been well retracted, a piece of a rib may require to be removed, thus exposing the diaphragm below the pleura, which must be incised and stitched to the margins of the wound, and the wound well packed with gauze.

The liver is now exposed, and two methods of procedure are open to the operator—either to push a pair of dilating forceps along the needle, which has been left *in situ*, and thus to open up the cavity and evacuate the pus, and then, after inserting a double drainage-tube, to wash out the cavity with the quinine solution mentioned above, close up the wound, fix the drainage-tube in position, and dress the wound aseptically, or to adopt Manson's special apparatus.

Manson, after the preliminary incision, thrusts a trocar and cannula into the abscess, and, after withdrawing the trocar, passes a drainage-tube stretched on a probe into the abscess cavity, and then, withdrawing first the trocar and then the probe, the drainage-tube is left in position in the liver abscess, and, being firmly gripped by liver tissue, prevents leakage of pus into the abdominal cavity.

2. *Operation through the Abdominal Wall.*—The usual method is to cut down upon the swelling or on to the liver, and if adhesions are found, to evacuate and drain the abscess. If there are no adhesions, the liver is fixed to the peritoneum by a few stitches of thick catgut or kangaroo tendon, but preferably not silk, and the wound is lined by iodoform gauze and left for two days, when, adhesions having formed, the abscess can safely be evacuated as described above. Manson's apparatus can, of course, be used in this position as well as through the thoracic wall.

Post-Operative Treatment.—The dangers of the operation itself are but slight. The pleura may be opened, and if this happens, it should be carefully closed by stitches.

The post-operative complications are many, and include hæmorrhage, pneumothorax, pyothorax, pyopneumothorax, gangrene of the lung, and delayed chloroform poisoning, while a second abscess is not uncommonly met with, and must be relieved.

After the operation the temperature should fall to normal, and if this does not happen, a second abscess or one of the above complications may be suspected, unless, indeed, it is due to imperfect drainage, which must at once be rectified.

The dressings should at first be frequently changed, usually twice a day, and the cavity irrigated with quinine lotion. Good drainage is the essential of the post-operative treatment, and care must be taken that the drainage-tube is not too rapidly shortened, otherwise the temperature is apt to rise.

On recovery, the patient should, if possible, be given a holiday in the Temperate Zone. A short course of ipecacuanha after the operation wound has quite healed is distinctly indicated in order to prevent the formation of another abscess.

OPISTHORCHIOSIS.

Definition.—Opisthorchiosis is an invasion of the bile-ducts with *Opisthorchis noverca* Braun 1903 and *O. felineus* Rivolta 1885.

Remarks.—*O. noverca* is said to be common in dogs in India, but has only once been found in the dilated bile-ducts of an Indian in Calcutta, who died with dysenteric symptoms.

O. felineus has been found in the dilated bile-ducts, and incidentally also in the intestine of human beings, cats and dogs in Tomsk. It caused a form of hepatic cirrhosis.

CLONORCHIOSIS.

Definition.—Clonorchiosis is the invasion of the bile-ducts with *Clonorchis sinensis* Cobbold and *C. endemicus* Baelz.

Climatology.—These parasites occur in China, Indo-China, and Japan, *C. sinensis* being more commonly found in China, and *C. endemicus* in Japan. They were both until recently classified under the term *Opisthorchis sinensis.*

Pathology.—These parasites occur in dogs and cats, but the method of infection is quite unknown. In man they live in the bile-ducts, in the recesses in the wall of the dilated gall-bladder or of the bile-ducts, and in the duodenum. They may also be found in abscesses apparently unconnected with the liver. The ova are found in the alimentary canal and the fæces. The liver becomes enlarged, and may be darker in colour, while it is atrophied in the neighbourhood of the dilated ducts. The intestine may show catarrhal inflammation. Often the spleen is also enlarged, and there may be ascites or œdema. Ova have been met with in the abdominal lymphatics, while the flukes themselves have been found in a lumbar abscess. The blood shows an eosinophilia.

Symptomatology.—There is an abnormal appetite, but the general health remains good for some time, though the liver enlarges and becomes painful, while jaundice may be present. The spleen also enlarges. The disease is apparently very chronic, but towards the end emaciation, ascites, œdema about the feet and legs, and diarrhœa lead to death from exhaustion. Abscesses may form.

Diagnosis.—The presence of the worms can only be diagnosed by finding the eggs in the fæces.

Prognosis.—The prognosis is bad, as no cure is known.

Treatment.—An attempt may be made to kill the worms by thymol or *Filix mas ;* otherwise the treatment must be symptomatic.

Prophylaxis.—Nothing can be said as to prophylactic measures until the method of infection is known.

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CHAPTER XLVIII

DISEASES OF THE CIRCULATORY ORGANS, SUPRARENALS, AND THYROID GLAND

General remarks—Diseases of the circulatory system—Diseases of the suprarenals—Diseases of the thyroid gland—Diseases of the spleen—Diseases of the thymus—References.

DISEASES OF THE CIRCULATORY ORGANS.

Diseases of the circulatory organs are common in the tropics as well as in other parts of the world. Pericarditis and endocarditis are not as common as in other regions, probably because rheumatism is rare, and therefore they are due to such other causes as gonococcal infection, etc. Atrophies of the heart, especially brown atrophy, are quite common as the result of some general disease. Heart-block is rare, but has been met with. Rupture of a perfectly normal myocardium, the pericardium being intact, is recorded by Herzog as due to fracture of the second, fourth, and fifth ribs.

Atheromatous degeneration of the arteries is quite common, and aneurism is found, generally affecting the thoracic aorta, while varicose veins and varicocele are usual, and, associated with hypertrophy of the heart, are very common among rickshaw coolies.

Thrombosis is often met with as the result of typhoid fever and other diseases, and we have seen thrombosis of a coronary artery with myomalacia cordis or aneurism of the heart.

Chlorosis is rare, though we have seen cases in European and high-class native girls. Anæmia is common, being generally due to agchylostomiasis, malaria, or kala-azar. Leukæmia cannot be said to be very rare, and is either of the spleno-medullary type or the lymphatic type. Pseudo-leukæmia and Banti's disease are also known.

General dropsy not due to heart or renal disease is generally agchylostomiasis or beri-beri.

The parasites of the circulatory organs are the malarial parasites, the spirochætes, *Trypanosoma gambiense*, *Leishmania donovani*, *L. infantum Schistosoma hæmatobium*, *S. mansoni*, and the *Microfilariæ*.

Tropical Heart.

Under this heading MacLeod has described the conditions of palpitation and dyspnœa on going up hills, met with in persons who have resided long in the tropics. He assigns this to degeneration of the heart, brought on by the heat and by the exceptional work which it has to do owing to the changes in the circulation which result from the high temperature of the tropics. He considers this to be the basis of the syncopal form of heat exhaustion.

DISEASES OF THE SUPRARENALS.

We have met with Addison's disease once in a European, and twice with hæmorrhage into both the suprarenal capsules—once in a still-birth after a breech presentation in a native child, and once in a case of acute suprarenal hæmorrhage in a European lady. This last showed symptoms so remarkable in character that a brief description may be given.

Acute Suprarenal Hæmorrhage.

After a year's residence in Ceylon, a young English lady, four months pregnant, was suddenly taken ill with fever associated with an abnormally quick pulse, great tenderness above the umbilicus, and pain in the small of the back on both sides. After a short intermission the fever returned, and rose to 104° F., with a pulse of 130, and quick respirations ; the abdomen became much distended and very tender, and the bowels were constipated. All the organs were normal, as was the urine. Vomiting did not begin till near the end, when the tongue first became coated, and then dry. Hiccough intervened before death on the thirteenth day. Treatment was without success in any way, and an exploratory laparotomy revealed no abnormality beyond bowels distended with gas. On post-mortem examination, no pathological phenomena were seen, except hæmorrhages into both suprarenal capsules.

DISEASES OF THE THYROID GLAND.

Diseases of the thyroid gland are quite common in the parts of the tropics with which we are acquainted. Myxœdema has been seen by us in Ceylon ; goitres, parenchymatous and adenomatous, have been met with by ourselves in Ceylon, and by Singer in Abyssinia. Exophthalmic goitre has been especially noted as far from rare by Singer in Abyssinia and Émile in East and Central Africa, but is very rare in India and Ceylon. McGarrison believes that the goitre endemic in Gilget (Kashmir) is due to a living organism which exists in water and in the alimentary canals of goitrous individuals. He considers intestinal antiseptics have a marked curative effect.

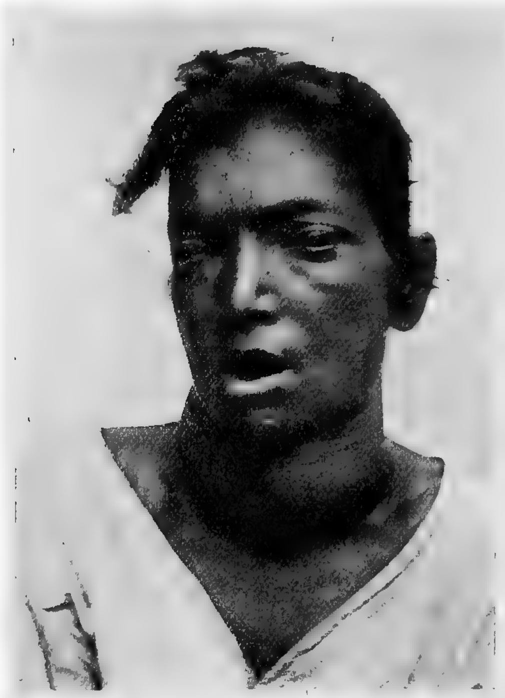

FIG. 341.—GOITRE IN A SINHALESE WOMAN.

DISEASES OF THE SPLEEN.

The spleen is affected in malaria, kala-azar, relapsing fever, etc., as already described. Capsulitis is very commonly met with in post-mortems, but splenic abscess is, in our experience, rare, and may be of entamœbic origin. Infarcts and tuberculosis are, however, not so rare, and spleno-medullary leukæmia, as has been mentioned above, is not very rare. Rupture of the enlarged malarial spleen has already been mentioned, and may cause death within a few minutes, or the patient may live for several hours.

DISEASES OF THE THYMUS.

Only once have we encountered a persistent thymus gland with some enlargement of the lymphatic glands, and this was in a case of sudden death.

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CHAPTER XLIX

DISEASES OF THE URINARY ORGANS

General—Urinary Schistosomiasis—References.

GENERAL.

RENAL disease in all its forms is frequently met with in the tropics, where nephrolithiasis, pyonephrosis, and pyelitis, with all their associated phenomena are by no means rare. Stone in the bladder is common in certain regions, as is prostatic hypertrophy. But the only disease which really concerns us in this work is urinary bilharziosis, caused by *Schistosomum hæmatobium*. Tumours of the bladder are not common in our experience. Prostatic abscess is met with at times. Native children in some parts of Africa (Sudan) suffer very often from a complaint called by the Arabs 'har boul,' characterized by severe burning on passing urine. This condition is due to concentrated acid urine and the presence of gravel.

URINARY SCHISTOSOMIASIS.

Synonyms.—Bilharziosis, Endemic Hæmaturia, Bilharzia Disease.

Definition.—Bilharziosis is infection with *Schistosomum hæmatobium* Bilharz 1852, the eggs of which irritate and invade the urinary tract, and cause hæmaturia and cystitis.

History.—The disease has been endemic in Egypt since ancient times, Ruffer having demonstrated calcified eggs of *S. hæmatobium* in mummies of the twentieth dynasty (about 1250-1000 B.C.). Hæmaturia was much noticed by the French army surgeons in 1799 to 1801; but it was not till 1851 that Bilharz made the discovery that the disease was due to *S. hæmatobium*.

Climatology.—Bilharziosis is prevalent in Africa, especially in Egypt and the Cape, but it is also met with in Asia, in India, Syria, and Mesopotamia, and in the West Indies. In Egypt, according to Sandwith, infection probably takes place in the early winter months when the floods have subsided.

Ætiology.—The cause of the disease is *S. hæmatobium*. The life-history, as far as is known, is described in Chapter XIV., p. 371.

The method of infection is unknown, but the eggs leave the body with the urine. Therefore it is possible that, as the parasite lives in water, infection may be by way of the skin or the mouth, but by which is not definitely known, though the skin infection has recently been supported by Williamson in Cyprus, who has shown that infection is connected with bathing in a certain river.

It occurs in any race and at any age, except infancy, but is more common in males than in females, due, it is thought, to the men washing in streams and working in the fields barefooted. According to Miss Elgood's investigations, the disease is common also in young girls, even in those who do not bathe and who use filtered water. It is rare in Europeans, being much more common among the natives, in whom it is especially prevalent among the working classes, especially the field-labourers.

Pathology.—The worms live in the portal vein, but proceed to the venules of the bladder to lay the eggs. The irritation of these eggs excites a round-celled infiltration, sometimes of a very extensive nature, giving rise to a sort of bilharzial granulation tissue—that is, a tissue composed of round cells and eggs. Madden divides the pathological changes into two classes—the hypertrophic and the atrophic. In the former, which is more common in mucous membranes, there is proliferation of the epithelium, with the formation of flattened projections or papillomata, while vesicles may also form, and, according to Madden, by bursting, give rise to the ulcers which at times are seen.

The ova may escape from the mucosa, according to Looss, without the aid of ulceration, by working their way between the epithelial cells into the lumen of the viscus. Underneath the mucosæ the round-celled infiltration forms the typical bilharzial granulation tissue, and leads to much thickening of the wall of the viscus, and, proceeding to connective-tissue formation, may cause marked changes. Lesions may also be found from the pelvis of the kidney to the meatus urinarius, but are most common in the bladder.

Morbid Anatomy.—The earliest changes are found in the bladder in the formation of a general infiltration and thickening of the mucosa with bilharzial tissue. Over this thickened mucosa is a layer of adherent mucus, which is apparently protective. In this mucus numerous eggs are found. Later hyperæmic patches are found associated with vesicles, which are especially marked around the trigone, and contain a whitish fluid in which are eggs. The hyperæmic patches increase in size and thickness, and the whole bladder becomes much thickened. Papillomata of all shapes and sizes are formed principally on the trigone and the posterior wall of the bladder. These papillomata bleed readily, giving rise to the hæmaturia.

As the eggs increase in amount, connective tissue forms round them, and they die and become calcified, thus giving rise to brownish-yellow, sandy patches, not protected by mucus, and leading to an atrophy of the mucosa of the viscus.

The urine collects in the hollows between the papillomata, and, decomposing, gives rise to phosphates, which produce a whitish incrustation on the bladder wall. The orifices of the ureters may become obstructed, giving rise to backward pressure, causing hypertrophy of the ureters and hydronephrosis. Septic infection is very liable to spread from the bladder up the dilated ureters to the kidney. Bilharzial tissue may also form in the ureters and the pelvis of the kidney, and take the form of infiltrations and papillomata. Calculi may also form in the bladder, and interstitial nephritis in the kidney.

As the bladder becomes infiltrated, it rises in the abdomen, and may be felt above the pubes, and in this situation infection may spread to the abdominal wall. In this case the typical bilharzial tissue forms in the subcutaneous tissue, and, working its way to the surface, forms a sinus lined with bilharzial granulations containing eggs and discharging pus. These sinuses may spread, and a large area of skin become involved.

Bilharzial tissue may also form in the prostate and urethra.

Symptomatology.—The incubation is not known, but, according to Sandwith, it varies from three to six months. At first no symptoms are exhibited, but in course of time frequency of micturition, with a sensation of burning in the perineum or along the urethra, may be noted, while there is some straining after passing urine. In due course hæmaturia appears, beginning with a few drops of blood either at the end of micturition or after the urine has been passed. Usually there are no symptoms with this hæmaturia, but there may be scalding. The urine is clear and acid, but some mucus may be passed, which, if centrifugalized or allowed to settle, shows the typical ova and, of course, red cells, leucocytes, and epithelial cells. Usually the general health is good, but pains in various directions may be felt—*e.g.*, in the back, the perineum, the gluteal region, or down the legs.

Sooner or later the urine begins to stagnate in the hollows in the mucosa formed by ulcers and by papillomata. When this happens the urine becomes alkaline and turbid, containing pus and phosphates, as well as decomposing blood and ova. With this decomposition of the urine cystitis appears, and the sufferings of the patient begin in earnest, with at first increased, and later almost constant micturition, scalding pains in the perineum and the scrotum, together with tenesmus, which increase until he can rest neither day nor night. In order to add, if possible, to his miseries, the prostate may enlarge or a stone may form in the bladder, which may be composed of uric acid or oxalates covered with phosphates, or simply of phosphates. If the bladder is examined in this stage, it will be found to be thickened, and may be felt above the pubes. Fistulæ may form in the abdominal wall above the pubes, or the urethra may be attacked. The urethral symptoms begin with localized pain and the formation of a lump, which develops an abscess, and later urinary fistulæ.

The patient now becomes weak and anæmic, and begins to suffer from pyonephrosis. The enlarged kidneys, and at times even the ureters, may be felt through the abdominal wall. In course of time septicæmia sets in, and the patient dies. On the other hand, cases which have left the endemic area may slowly recover, the ova ceasing to be passed.

Complications.—Retention of urine from blocking of the urethral opening by papillomata or a stone may occur. Stone in the bladder, as has already been mentioned, is an important factor in increasing the sufferings of the patient, but its symptoms may be masked by those of the disease. Urinary fistulæ has already been referred to, and cancer may also occur as a complication of the disease, but is said to be rare. Agchylostomiasis and pellagra and other diseases may also complicate a case.

Diagnosis.—The only certain diagnosis is by the discovery of the ova, but hæmaturia in the endemic area must always be regarded with suspicion. Centrifugalization is necessary when the ova are in small numbers.

Prognosis.—The prognosis depends largely upon the possibilities of infection, and is therefore better if removal from the infected area is possible ; for, according to Sandwith, most cases cease to pass eggs within three years of leaving that area.

Treatment.—No known medicine will kill the parent worms, though various treatments such as injections of sulphuretted hydrogen and carbon dioxide gases into the bladder, have been suggested. The drug most strongly recommended is the liquid extract of male fern, in 5-minim doses, three times a day, continued for a long time. It is said to reduce the hæmaturia and lessen the discharge of eggs. Madden recommends the washing out of the bladder with injections of silver nitrate, beginning with 1 in 10,000, and increasing the strength gradually ; or quinine in a 4 per cent. solution ; or adrenalin in normal saline solution.

In addition, boracic acid, in 5-grain doses, three times a day, or helminthol, in 15-grain doses, three times a day, urotropine, salol, benzoic acid may be given, or the ordinary buchu and hyoscyamus mixture may be administered. Large quantities of water or Vichy water should be drunk to wash out the urinary passages.

If a calculus is present, it must be removed by lithotrity or by perineal, not suprapubic, cystotomy. Cock's operation of cystotomy and drainage of the bladder gives relief in the later stages, but Madden says that this only lasts for a few days, and then usually diarrhœa and septic infection set in, and the patient dies in about two weeks.

With regard to fistulæ, they ought to be thoroughly dissected out, and this may mean a very prolonged operation if it is to do any good.

Prophylaxis.—As the method of infection is unknown, it can only be suggested that bathing in polluted or possibly polluted water is most dangerous, and drinking-water must be carefully boiled and filtered. The urine of persons suffering from the disease should be mixed with some disinfectant before being disposed of.

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CHAPTER L

DISEASES OF THE GENERATIVE ORGANS

General remarks—Endemic funiculitis—Sutika—References.

GENERAL REMARKS.

MOST of the diseases of the male and female generative organs are cosmopolitan, and exhibit but little difference in the temperate and tropical regions. Syphilis and gonorrhœa are very common. With regard to the former, some authors assert that it was originally a disease of the East. Neglected strictures are by no means uncommon, and, as we have already stated, one of these apparently caused intestinal obstruction and death. Extravasation of urine is not rare—at all events, in Africa—as the result of neglected stricture. Elephantiasis of the generative organs is common in Africa and in Ceylon. Hydroceles, chyloceles, hæmatoceles, orchitis, and epididymitis are all common. Displacements, inflammations, and tumours of the female generative organs are quite common, especially uterine fibromata and ovarian cysts. Bilharziosis is capable of attacking both male and female generative organs, as has already been noted.

Malignant disease is most commonly epithelioma of the penis and cancer of the uterus. With regard to the former, we are inclined to associate it—at all events, at times—with phimosis and the accumulation of irritating secretions, which may cause a balanitis. In these circumstances, if no treatment is carried out, epithelioma results. Certainly epithelioma of the penis is rare in races in which circumcision is performed.

The deaths of women directly associated with child-birth are considerably higher in the tropics than in the temperate zone. Thus, those of Ceylon are three times as many as those of England, and more than half of them are entered as being due to puerperal fever. In India, Pearse has recently drawn attention to the deaths caused by a puerperal diarrhœa called 'sutika,' with reference to which more will be said later.

Fœtal monstrosities and abnormalities appear to be much commoner in the tropics than in the other parts of the world, or else we have been singularly fortunate in meeting with them. This is hardly the place to give a classification of these abnormalities, but we should advise the tropical practitioner to have some elementary ideas, at all events, on the subject. We have met with the following: Fœtus papyraceus, cyclops, agnathia; several double monsters of both general types, including some specimens of janus; acephalic monsters; and rachischisis, meningocele, non-development of the eye, coloboma iridis, hare-lip, cleft-palate, branchial fistula, non-development of the thigh. Macrodactylism has been reported from the Philippines, and pes gigas from China.

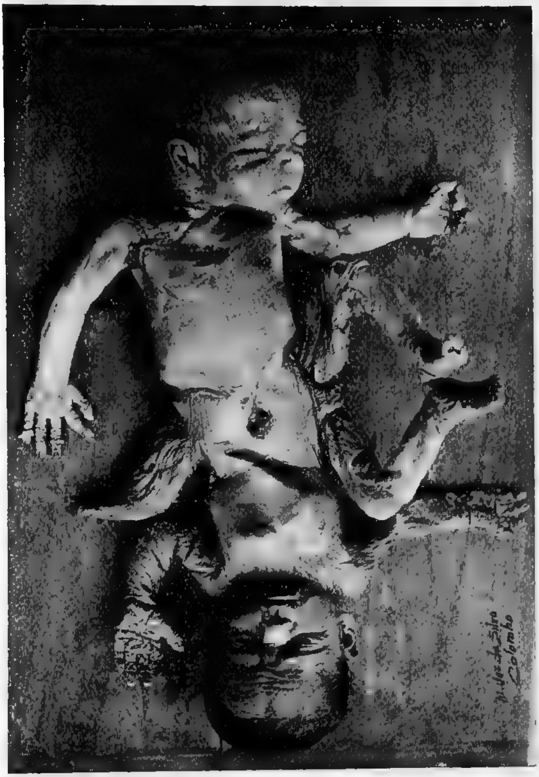

FIG. 342.—ISCHIOPAGUS TRIPUS.

With regard to the breast, we have seen extraordinary hypertrophy of the male and of the female breast. Cancer of the breast is relatively much rarer in the tropics than in the temperate regions, though it is fairly common. The parasite *Gnathostoma siamese* Levins, mentioned in Chapter XVI., belongs to the connective tissue, though it happened to be found in the breast of a young Siamese woman.

Certain diseases, however, require special reference, and these are endemic funiculitis and sutika.

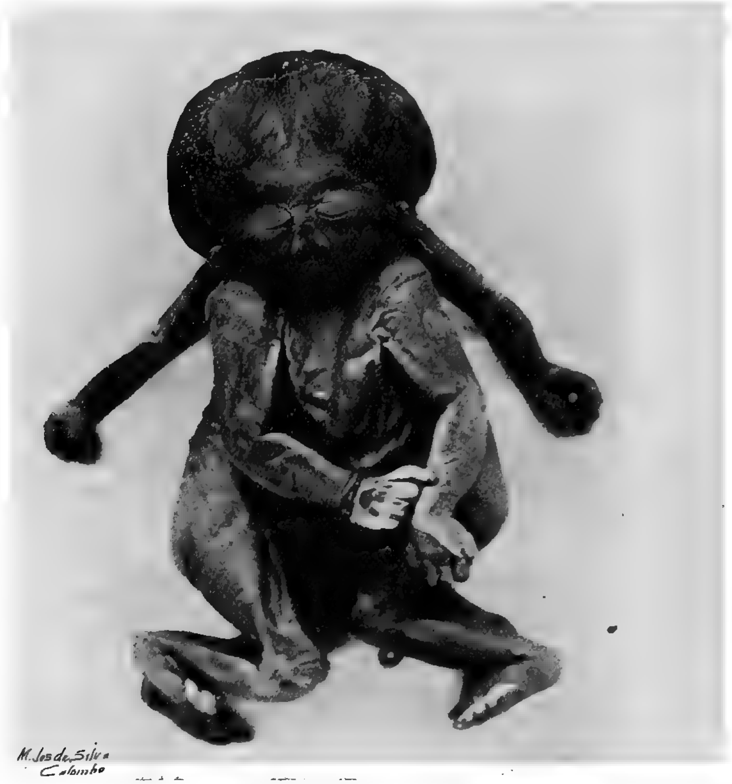

FIG. 343.—SYNCEPHALUS OR JANUS.

(This form of monster is fairly common in Ceylon.)

ENDEMIC FUNICULITIS.

Synonyms.—Suppurative Phlebitis of the Spermatic Cord, Suppurative Corditis, Cellulitis of the Spermatic Cord.

Definition.—Endemic funiculitis is an acute specific suppurative inflammation of the spermatic cord, of which the ætiology is not firmly established.

History.—For many years medical men practising in Ceylon have noticed the occurrence of a peculiar form of acute suppurative inflammation of the spermatic cord, which occasionally takes a true epidemic character, numerous cases occurring within a short period. References to this affection may be found in almost all the medical reports for the colony during the last twenty years, the disease being variously indicated by the name of phlebitis of the cord or corditis. It was considered by some to be of traumatic origin, by others of venereal origin. Some practitioners considered it to be a malarial affection. The disease was investigated by Castellani first in 1904, and more completely in 1907. He came to the conclusion that it had nothing to do with either malaria or gonorrhœa. He thought the malady had sufficiently characteristic

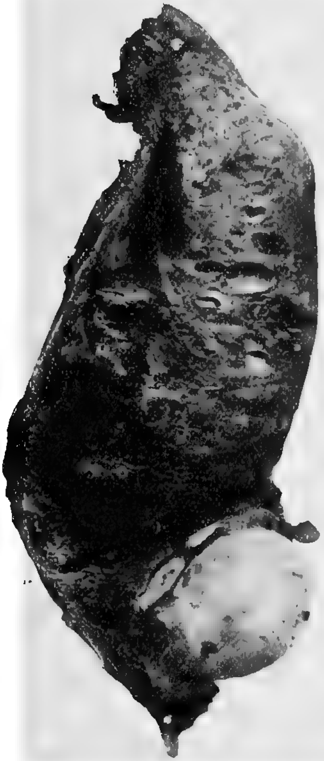

Fig. 344.—Endemic Funiculitis, showing Longitudinal Section of the Cord.

The testes and epididymis are normal.

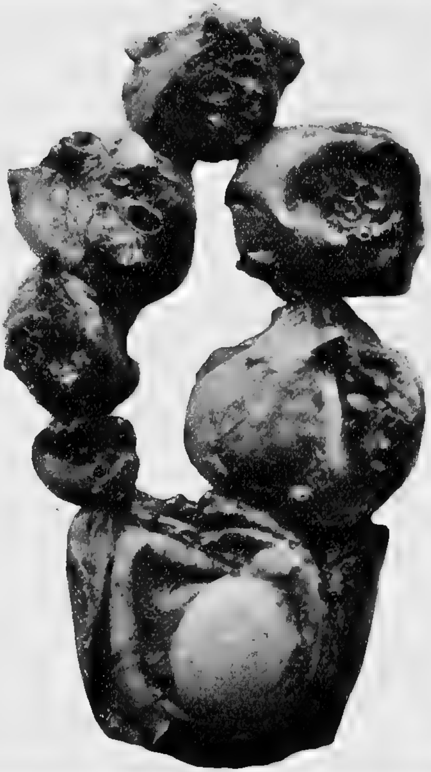

Fig. 345.—Transverse Sections of the Cord in Endemic Funiculitis.

The testes and epididymis were normal, but the tunica vaginalis held a small quantity of fluid. The sections of the cord are arranged in an arch from right to left. The dilated veins, which were filled with pus, are clearly visible.

symptoms to be ranked as a separate disease, and suggested the name 'endemic funiculitis.' The affection is not limited to Ceylon, as cases occur in Southern India, and an identical pathological condition has been described in Egypt by Madden in 1907 under the name of cellulitis of the spermatic cord. Of great importance are the recent investigations by Coutts.

Ætiology.—Among Ceylon practitioners, the disease was considered by some to be of traumatic origin ; others considered it to be of venereal origin, and yet others to be a malarial affection. Castellani has found in all the cases diplo-streptococci, and in two cases, one in 1904 and the other 1909, a microfilaria.* The cocci are practically indistinguishable from the ordinary streptococci but for the fact that some decolourize by Gram in sections of the tissues, and in smears from the pus, while they are Gram-positive in cultures. Further researches are necessary to decide whether this diplo-streptococcus is the primary cause of the disease, or more probably a secondary agent playing a rôle only in the suppurative stage of the malady. According to Coutts, these micrococci are often found in the urethra of natives. He regards the suppurative condition of the cord as due to the extension of an infection from the urethra by way of the vas deferens.

Pathology.—The whole of the spermatic cord is highly inflamed and infiltrated. The circumference of the cord may be as much as 3 to 3½ inches. The tunica vaginalis is hyperæmic, but in most cases there is no collection of fluid. On making a transverse section of the cord, yellow creamy pus will exude from the opened veins of the pampiniform plexus, as well as from the vas deferens. The inflammation is not localized to the cord only ; it ordinarily extends to the epididymis. In two very recent cases of ours, however, the epididymis was normal. The testicle proper remains always unaffected ; there is occasionally some effusion of clear fluid into the tunica vaginalis. The histological lesions are, briefly, the following: The veins of the pampiniform plexus are much dilated, and present a cellular infiltration of all the coats, the lumen of some veins being occupied by pus cells or thrombi. The vas deferens also presents a well-marked cellular infiltration of its mucous membrane and various muscular coats. The type of cellular infiltration as noted by Coutts and Castellani is mostly mononuclear.

Symptomatology.—The disease begins suddenly, generally after a hard day's work or severe exercise. In Ceylon the usual history is as follows : The patient, after an extra hard day's work, comes home in the evening very tired, but not feeling unwell, and takes a cold bath as usual. After the bath he is suddenly seized with a shivering fit, the temperature rising very high. He feels very sick, and there is often actual vomiting. At the same time he complains of pain along the cord and the epididymis. The condition becomes rapidly worse, and the patient is generally taken to hospital on the second or third day of the illness. On admission, it is usually found that the general condition is grave. There may be continuous vomiting, and occasionally hiccough; the temperature is generally above 102° F., and the pulse small and frequent. At the physical examination it will be seen that the inguinal region is occupied by a large cylindrical swelling in the direction of the cord. The swelling is very tender on pressure, and hard; the skin is not affected. Generally the epididymis is somewhat enlarged and tender, though in some very recent cases it may not appear to be affected. In all cases the testicle proper appears to be normal; there is, as a rule, no effusion in the tunica vaginalis. The affection is generally localized to one side only, but occasionally attacks both sides. On examination of the penis and scrotum no ulcers will be found, no signs of gonorrhœa, and no signs of any traumatic lesions, though in several cases the patient gives a history of having made an effort of some sort. As a rule, the disease has no tendency to spontaneous recovery. If an operation is not performed in time, signs of general septicæmia usually set in. In such cases the skin of the patient often becomes jaundiced, cutaneous hæmorrhages may appear, the fever is of an intermittent or remittent type, the pulse becomes extremely small, there is often hiccough, and the patient dies in a few days.

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* This microfilaria is apparently somewhat different from *Microfilaria bancrofti*, because though possessing a tight-fitting sheath, it is capable of translation movement. It has also been found in a third native, who was in good health.

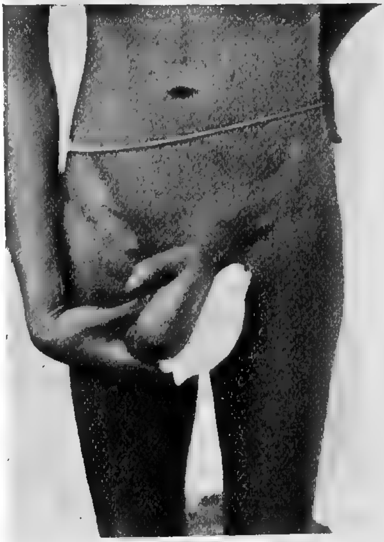

FIG. 346.—ENDEMIC FUNICULITIS IN A SINHALESE MAN.

Prognosis.—This is serious in the ordinary acute form. If an operation is not performed in time, symptoms of general septicæmia set in, and the case, as a rule, ends fatally.

Varieties.—A mild form, with thrombosis of the veins, but without suppuration, is at times met with. According to Coutts, a chronic form, also without suppuration, may occur.

Diagnosis.—The disease is apt to be confused with strangulated hernia and an acute elephantoid condition of the testicle and cord. From the former endemic funiculitis may be differentiated by the history, the high fever, and the course, which is somewhat less acute. In some cases, especially in the fulminating forms, operative treatment alone will clear the diagnosis.

From an acute elephantoid condition it may be differentiated by the absence of the erysipelatous-like redness of the skin.

Treatment.—Except the rare mild forms, when lead lotion and icthyol ointment, with or without ice application, may be sufficient, the only effective treatment is surgical, and orchiotomy, with section of the inflamed cord as high up as possible, is imperative. Coutts recommends exposure of the inflamed cord by a free incision through the skin and external oblique, to be followed by numerous incisions into the tumour. The wound is left open, and fomentations applied till the surface is clean. The wound is then left to heal by granulation. Coutts considers that in this way, though the testis loses its generative function owing to the obliteration of the spermatic duct caused by the inflammation, its internal secretion is unimpaired.

When the disease has extended beyond the internal abdominal ring, orchiotomy must be performed and the veins left unligatured while fomentations are applied.

SUTIKA.

Synonym.—The Puerperal Diarrhœa of Bengal.

Under the above term Dr. Pearse, the Medical Officer of Calcutta, gives an account of a chronic diarrhœa associated with fever which causes a death-rate of 1·3 per cent. on the total number of registered births in Hindu and Mohammedan puerperal women of all ages in that city.

The disease begins with diarrhœa some two or three weeks after delivery, there being five to fifteen watery, frothy, fermenting motions per diem without blood or mucus. Along with the diarrhœa there may be loss of appetite and dyspeptic symptoms, rarely vomiting, but no griping pains or abdominal tenderness. The temperature is raised, and an irregular fever lasts throughout the illness. There is no vaginal discharge ; œdema of the feet is noted as a late symptom. The course of the disease varies. Sometimes it is rapid, and kills the patient in a few months ; more usually it lasts five to eight months, and less usually it continues for more than twelve months. Towards the end the patient becomes weak and emaciated, and dies of exhaustion. The case-mortality is not known.

The nature of this disease is obviously obscure, and requires investigation.

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CHAPTER LI

DISEASES OF THE LYMPHATIC SYSTEM AND SEROUS MEMBRANES

General remarks—Climatic bubo—Volvulosis—References.

GENERAL REMARKS.

THE lymphatic system is affected in many general diseases—as, for example, in plague and trypanosomiasis—and in cosmopolitan affections like septic disease, syphilis, tuberculosis, etc. In addition, there is the enlargement of the glands in the inguinal region called 'climatic bubo,' and the various pathological phenomena caused by *Filaria bancrofti*. These morbid changes are varices of lymph-channels, inflammations, and elephantiasis, and have already been discussed in the chapter on Filariasis. The pathological changes caused by *Filaria volvulus* must be mentioned here.

With regard to the serous membranes, pleurisy and empyema are common, while peritonitis from the perforation of a typhoid ulcer, or the perforation of the bowel by an *Ascaris*, as has been recorded by Ziemann in the Cameroons, or from the extension of some septic area—*e.g.*, a gonorrheal salpingitis—are all met with. Chylous ascites is rare.

CLIMATIC BUBO.

Definition.—Climatic bubo is the enlargement of the inguinal glands associated with pain and fever, the cause of which is unknown.

History.—The history of this disease only dates back to 1896, when Ruge reported several cases suffering from inguinal buboes, in which the usual causes of such an adenitis were all absent, and he was therefore inclined to consider the disease a separate entity dependent probably on climatic influences. About the same time Goding, independently of Ruge, published a series of observations apparently of the same nature, while more recently cases have been reported by many observers.

Climatology.—The chief geographical distribution of climatic bubo is the East Coast of Africa, the West Indies, the Straits Settlements, and China, but it may be met with in any tropical and subtropical region. Le Dantec quotes cases occurring in Mauritius, Tonkin, and Madagascar. Low and Castellani have described a case in Uganda, while Luzzati has met with several cases in Chili. We have observed cases in Ceylon, and Skinner has described numerous cases in Bengal. Climatic bubo may also occur in the temperate zone, for Scheube has come across several cases in Japan, and Gabbi in Scicily.

Ætiology.—Though various micro-organisms have been described, the ætiology of the disease is still obscure. Ferraro, from one of his cases, isolated an organism practically identical with *Bacillus pestis.* Hewlett isolated from the affected gland a bacillus not decolourized by Gram, the characters of which were somewhat similar to those given by Kitasato in his first description of *B. pestis;* for Kitasato stated at first that the *B. pestis* was not decolourized by Gram. Low and Castellani were not able to grow any organism from their case. Some authors have isolated the ordinary pyogenic cocci.

Martin, Suger, Le Sueur, and Fleurant consider climatic bubo to be a manifestation of malaria. Schimm believes the bubo to be secondary to some intestinal infection.

According to Cantlie, climatic bubo is a form of attenuated plague —*Pestis minor*—basing this opinion on the fact that in Hong-Kong he observed several cases of so-called climatic bubo to precede the outbreak of an epidemic of true plague. He has been confirmed in his opinion by Hewlett's discovery mentioned above. Cantlie's theory is supported by Luzzatti, who considers the climatic bubo to be a form of *Parapestis.*

In our opinion, climatic bubo is a disease *per se*, and is not related to plague.

Pathology.—The results of our histological researches agree better with those obtained by Vanzetti in Italy on the material collected in South America by Luzzatti than with those of other authors.

The capsule of the affected gland is much thickened, and the interstitial tissue is very abundant. There is great proliferation of lymphocytes, and hæmorrhagic foci are noticeable here and there. Very characteristic is the presence of numerous typical plasma cells, while the so-called retractile Recklinghausen cells found in plague are absent. The histological structure of climatic bubo is, therefore, totally different from that of the plague bubo, in which, as was shown by the classical histological investigation of Dürck, plasma cells are absent or extremely rare, while the so-called retractile Recklinghausen cells are numerous.

Symptomatology.—After perhaps two or three days of vague malaise and slight fever, the patient complains of pain, which increases on walking, in one or both of the inguinal regions. On examining the parts, one or more inguinal glands, or occasionally the crural glands on both sides, or more frequently one side only will be found to be enlarged, very painful on pressure, and hard. There will be no signs of lymphangitis present. The glands may become greatly enlarged, reaching the size of a hen's egg or larger, but in most cases do not suppurate. Aspiration by means of a syringe will draw only a little gland-juice, occasionally blood-stained, but no pus. The liquid will be found to be sterile.

Fever is often present of an irregularly remittent or intermittent type. It rarely exceeds 102° F.; and is higher at night than in the morning. The duration of the disease is variable from a few days to several weeks, and rarely months. In time the pain in the affected region gradually disappears, the size of the enlarged glands decreasing. As a rule, the affected glands remain larger than normal, but not painful, long after the illness is over. Occasionally a relapse occurs. The general health is not much affected, though the patient may be very weak and unfit for work. The spleen is not enlarged. The examination of the blood may reveal a slight leucocytosis; the urine is normal. Occasionally a trace of albumin may be present. Intestinal symptoms are generally absent.

Clinical Varieties.—In our experience an acute, a subacute, and a chronic type of climatic bubo may be distinguished. *The acute type* is always accompanied by fever and severe pains in the affected glands. All the symptoms disappear within five to ten days. In *the subacute and chronic type* lasting from a few weeks to several months the onset may be insidious, and fever may be absent altogether. Moreover, in some cases the periglandular tissues become inflamed, suppuration may take place, and fistulous tracks may develop.

Diagnosis.—The absence of soft chancre on the genital organs will exclude *venereal bubo*; the absence of lymphangitis, infected wounds, insect-bites on the legs and feet will exclude the ordinary symptomatic bubo. In contrast to plague, the patient does not look very ill, but the only satisfactory way to differentiate acute climatic bubo from a mild case of plague is the puncture of the affected glands and the bacteriological examination of the gland-juice. To do this the skin of the inguinal regions is thoroughly cleansed with spirit and ether, then disinfected with a perchloride (1 in 1,000) or carbolic lotion (5 per cent.), then washed again with ether or spirit. One of the enlarged glands is then aspirated with a sterilized syringe. The gland-juice which is drawn off is then examined microscopically and by culture method in the ordinary way for the presence of the plague bacillus.

Climatic bubo is generally easily distinguishable from attacks of filarial lymphadenitis, which is generally accompanied by very high fever and severe lymphangitis, and an erysipelatous-like condition of the leg. During and after various intestinal infections—as, for instance, typhoid and paratyphoid—occasionally a suppurative inflammation of some lymphatic glands—sometimes the inguinal glands—occurs. In such cases the history of the case—the fact that the bubo comes, as a rule, to suppuration—and the bacteriological examination of the gland-juice, which in true climatic bubo is sterile, will clear the diagnosis.

Prognosis.—The prognosis is favourable, though a relapse may occasionally occur shortly after the first attack is over, sometimes on the side previously affected, sometimes on the other side.

Treatment.—The treatment is merely symptomatic, consisting of complete rest, application of lead lotion on the affected region, or an ichthyol and belladonna ointment, together with the administration of a mild aperient, and, if there is much pain, a hot fomentation locally, together with small doses of opium by the mouth. In the rare cases, where signs of suppuration are noticeable, incision of the glands is necessary, using the ordinary aseptic precautions. In protracted cases complete surgical removal is the best treatment. When the glands remain enlarged after the acute stage has passed off, local applications of tincture of iodine, iodine valsol, or an ointment composed of 30 grains each of lead iodide and potassium iodide to 1 ounce of vaseline, may be of benefit.

VOLVULOSIS.

Definition.—Volvulosis is a disease caused by *Filaria volvulus* Leuckart 1893, and characterized by the formation of fibrous, cutaneous, or subcutaneous tumours.

History.—As already mentioned in the chapter on Nemathelminthes, these tumours were discovered by a German medical missionary to contain worms, which were described by Leuckart in 1893, and subsequently the disease and its causative worm were studied by Labadie-Lagrave and Deguy in 1899, Prout in 1901, Brumpt in 1904, Ziemann and Védy in 1907, and Fülleborn in 1908, the last paper being a most valuable contribution to our knowledge of the subject.

Climatology.—The disease is found in Africa, at Sierra Leone, on the Gold Coast, and in Dahomey, Cameroons, and the north-east of the Congo, where it is variously stated to affect from 1 per cent. to 10 per cent. of the population, being distributed along the banks of rivers.

Ætiology.—The disease is caused by *Filaria volvulus* Leuckart 1893, but the method by which this worm is introduced into the human body is quite unknown, as is also its life-cycle outside human beings. Brumpt has, however, suggested that it will probably be found in a tsetse-fly.

Pathology.—The adult worms lie in lymphatics, the anterior end of the female being in close approximation to the posterior end of the male, because the apertures of the genital apparatus lie in these positions. By some means—possibly by the presence of the Microfilaria, or possibly by toxic waste-products—these worms irritate the lymphatics, causing lymphangitis and perilymphangitis. These inflammatory processes eventually lead to the formation of a fibrous capsule around the worms, which then lie in a portion of a vessel cut off (?) from the rest of the lymphatic system, and which forms a fibrous subcutaneous nodule containing male and female worms and Microfilariæ.

On opening one of these tumours, it is seen to consist of a capsule of fibrous connective tissue, beneath which is some soft caseous material composed of endothelial cells, granular débris, and Microfilariæ, and encloses a central space containing a greenish, semi-purulent fluid. The worms, which are usually cut across in several places when opening the tumour, lie partly in this central cavity and partly in narrow twisted tunnels, which ramify through the walls of the fibrous capsule, giving it a network-like appearance. Sometimes the central cavity is not obvious, and only the network of tunnels is seen ramifying through the connective tissue.

Symptomatology.—The disease, as a rule, begins insidiously with malaise, weakness, vague pains in various regions of the body, and irregular fever, but it is said that at times attacks of lymphangitis may be noticed. In due course a tumour is discovered in the sub-occipital region, the elbow, axilla, side of the chest, iliac region, gluteal region, or popliteal space. These tumours vary in size from a pea to that of an egg, and lie in the skin or subcutaneous tissue, in which they are freely movable. They may be elastic if they contain fluid, or firm if composed mainly of fibrous tissue. They usually remain quiescent for years, and but seldom ulcerate.

Diagnosis.—The presence of an elastic tumour somewhat resembling a lipoma, or of a firm fibrous tumour in any part of the body of a person who has resided in the endemic region, should arouse suspicions as to the presence of *Filaria volvulus*.

Prognosis.—These little tumours are not in any way dangerous to the life or health of the patient.

Treatment.—Removal by incision and enucleation is quite easy, and devoid of danger.

Prophylaxis.—As the life-cycle of the parasite is unknown, nothing can be said as to prophylaxis.

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CHAPTER LII

DISEASES OF THE CONNECTIVE TISSUES, MUSCLES, BONES, AND JOINTS

General remarks—Somatic tæniasis—Dracontiasis—*Filaria loa*—Calabar swellings—Goundou—Endemic hypertrophy of the os calcis—Mycetoma—References.

GENERAL REMARKS.

THE diseases of the connective tissues which concern us are mostly parasitic, being caused by the cysticerci of tapeworms, but round worms are also commonly met with, especially the Guinea-worm.

With regard to muscles, the only disease which need be mentioned is trichiniasis, which is said to be far from rare in Northern India. Necrosis, caries, and tumours of bone are not uncommon, but rheumatoid arthritis is rare, and tubercular disease, at present, is very rare. Gonorrhœa and post-dysenteric arthritis are met with, and filarial synovitis of the knee-joint has been described by Maitland. Gout is rare, but we have seen a typical case in a native who had never left Ceylon.

SOMATIC TÆNIASIS.

By somatic tæniasis is meant the invasion of the body by the cysticercus of cestode worms. The subject is, therefore, divisible into—(*a*) cysticercosis, or infection with the larvæ of *Tænia solium*, which occurs now and again in the connective tissue of muscles, fasciæ, and in the brain; (*b*) echinococcosis, which is the infection of the body with the hydatids of *Echinococcus granulosus*, and of which we have only met with one example in the tropics, and even then it was imported; but, judging by Begbie's recent observations, it would appear as though the disease was endemic in Ceylon; (*c*) sparganosis, which is the invasion of the body by *Sparganum mansoni*, *S. baxteri*, or *S. proliferum*, all of which have been sufficiently described in Chapter XV.

DRACONTIASIS.

Synonym.—Dracunculosis.

Definition.—Dracontiasis is the infection of man with *Filaria medinensis* Linnæus 1758, the Guinea-worm.

History.—The history of the infection, together with the description of the worm and its life-history, have already been given in Chapter XVI. (p. 417), to which reference should be made. Scheube states that Cholodkowski has described an unclassified *Filaria*, several inches in length, which causes ulceration of the fingers, and even gangrene, in Tiver, in Russia, which may or may not be the same worm.

Climatology.—Dracunculosis is a disease of the tropics, especially of tropical Africa, and particularly of the West Coast. It is also known in Asia Minor, Persia, and India. Although coolies infected with the worm frequently pass from India to Ceylon, we have no evidence that the latter island has so far become infected. It is also known in the Fiji Islands. It was introduced into America by the negro slaves, and has become endemic in British Guiana and Brazil.

Symptomatology.—The worm as a rule produces no symptoms until a little vesicle appears on the skin, or the outline of the worm is noticed under the skin, but urticarial eruptions have been observed by several authors and ourselves. The little vesicle bursts, leaving a round hollow, out of which exudes a clear fluid full of larvæ, and at the bottom of which lies the vaginal orifice of the worm. After discharging a certain amount of fluid, the anterior end of the worm extrudes through the skin opening, and is either twisted on a stick or fixed in position by a piece of string by the native patient. It is not advisable to pull vigorously on the protruded piece of worm, as it is liable to break, and if this happens a serious inflammation of the affected area may result. The wound usually quickly heals after the worm has finally been extracted. The usual site for it to appear is about the feet or legs, more rarely the hands or arms, and still more rarely the head or trunk.

But all cases are not so simple, and aching or dragging sensations, sometimes accompanied by rigors and fever, may occur. Rarely it enters a knee-joint and causes synovitis or arthritis. Usually there is only one worm, but there may be more.

Dudgeon and Child have investigated the blood in this disease, and find a marked eosinophilia. The average differential count was as follows: Polymorphonuclears, 63·6 per cent.; lymphocytes, 18·4 per cent.; large lymphocytes, 2·8 per cent.; mononuclears, 1·6 per cent.; eosinophiles, 13 per cent.

Diagnosis and Prognosis.—There is no difficulty in the diagnosis, and the prognosis is good.

Treatment.—It is a good plan to massage the area above the vesicle, and try with a little patience to get the worm out whole, or, if it is visible under the skin, to make an incision and remove it. Natives extract the worm by twisting the protruding portion on a stick, every day giving a turn or two. A better plan is to douche frequently with water the part occupied by the worm until she gets emptied of all the embryos, which generally takes place in from two to three weeks. When all the embryos have been exuded, the worm is either absorbed or tends to emerge, and no longer resisting extraction, can be easily removed. It has been advised (Emily) to inject a 1 per 1,000 solution of perchloride of mercury into the swelling caused by the worm. But this is very painful, and does not appear to be very successful. Some authors have advised the injection of 10 to 15 minims of a 2 per cent. solution of cocaine into the protruding portion of the worm.

Prophylaxis.—The prophylaxis is very simple—viz., the drinking of only boiled and filtered water.

FILARIA LOA.

Filaria loa has frequently been noticed in the ocular and palpebral conjunctivæ, crossing the bridge of the nose, in the skin over the sterno-mastoid muscle, or that of the scalp, the fingers, the penis, etc., and much more rarely in the anterior chamber of the eye, though accounts of its presence in the vitreous humour require confirmation. The geographical distribution of the worm has already been given (p. 422). In our experience it usually causes but little disturbance, but at times, when in the conjunctiva, it is associated with piercing and lancinating pains, uncertain vision, and swelling of the eyelids. It can be removed by an incision and careful traction.

CALABAR SWELLINGS.

Synonyms.—Kamerungeschwülste, Tropical Swellings.

Definition.—Calabar swellings are smooth, temporary, slightly raised tumours on the head, arms, hands, ankles, and feet, probably caused by the presence of *Filaria loa* in the subcutaneous tissue.

History.—For many years it has been known that peculiar swellings occurred in the people living in Old Calabar, and in due course accounts appeared in works of travels in West Africa, but it was not till 1895 that Argyll Robertson described them as a distinct disease, using their popular nomenclature. In subsequent years he published several accounts of his cases. In 1898 Plehn drew attention to the complaint, and in 1899 Thompstone published an account of a case, while Habershon and Kerr in 1904, Wurtz and Clere and Stephens in 1905, and Ward in 1906, have all added to the literature of the subject.

The paper by Ward is, however, of especial interest, as it deals fully with the history of the disease.

Climatology.—The disease is only known on the West Coast of Africa, particularly in the regions of Southern Nigeria and the Cameroons.

Ætiology and Pathology.—There is a consensus of opinion that in some way these swellings are caused by *Filaria loa*, but this has never been definitely proved.

The way in which the worm induces these peculiar lumps is a matter of conjecture, Argyll Robertson assigning them merely to the movements of the parasite. But this cannot be so, otherwise the swellings would occur as they cross the bridge of the nose, which they can do without any such disturbance.

The next theory is that the parasite irritates the skin, causing the patient to rub the affected area, which in this way becomes mechanically inflamed. This theory was originally propounded by Manson, who has relinquished it in favour of another and better explanation.

Two other theories suggest that the parasite, by irritating the nerve endings, either directly or by reflex action, causes the swelling; but this does not appear likely, as they ought to occur wherever the worm travels. Manson in 1903 suggested that they might be brought about by the expulsion of the Microfilariæ from the uterus of the parent worm, and this appears not unlikely, and would explain their evanescent character.

Ward is not satisfied with Manson's theory, and suggests that they may be due to the expulsion of waste products from the worm.

Age, sex, and employment have no influence in the causation of the complaint.

Symptomatology.—Sometimes without prodromal symptoms, or at times after some nausea and headache, swellings appear on the head, face, arms, wrists, hands, fingers, ankles, or toes, less commonly on other parts of the body. The reason of this distribution, according to some authors, is believed to be the small amount of connective tissue in those regions. The swellings are smooth, firm, slightly-elevated areas, generally about the size of half a goose's egg (5 to 8 centimetres), often painless, though this is not invariable. There is either absence of or only very slight pruritus. They are hot, and do not pit much on pressure. They appear quickly, last for two or three days, and disappear gradually or rapidly, and are always associated with an intense eosinophilia. In many cases only one swelling appears at a time.

Stephens gives the differential count of his case as—polymorphonuclears, 26 per cent.; lymphocytes, 23 per cent.; mononuclears, 1 per cent.; eosinophiles, 50 per cent.

Diagnosis.—There is no difficulty in recognizing these fugitive swellings in persons who have resided in the endemic region.

Prognosis.—They have never been known to cause serious symptoms, but may recur for many years after the patient has left the tropics.

Treatment.—This is unsatisfactory, but cool applications may be made to the swellings and an ichthyol ointment or lotion applied.

Prophylaxis.—As the life cycle of *Filaria loa* is unknown, it is not possible to lay down rules for the prophylaxis.

GOUNDOU.

Synonyms.—Anákhré = big-nose ; Henpuye = dog-nose.

Definition.—Goundou is a disease of unknown causation, characterized by a bony swelling, usually bilaterally symmetrical, situated on either side of the nose.

History.—The disease was first described by Macalister in 1882, under the term of 'the horned men of Africa.' Lamprey in 1887 also referred to the disease under a similar term, and Strachan drew attention to it in a West Indian child in 1894. Maclaud in 1895 described the disease which he saw on the Niger under the terms 'goundou' or 'anákhré.' In 1900 Chalmers gave an account of the disease as seen on the Gold Coast, and Renner as seen in Sierra Leone. Later Braddon recorded a case in Malaya, and others found the disease in Sumatra and in China. Friedrichsen gave an excellent description of it as seen in East Africa, and Nell gave an account of his cases on the Gold Coast, while Cantlie records a case in a European. Lastly, Rogers and Bouffard have recorded a case in a monkey—Papio sphinx.

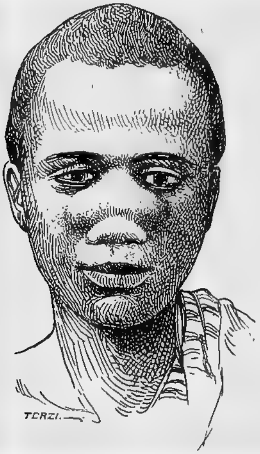


FIG. 347.—GOUNDOU IN A NATIVE OF THE GOLD COAST.

Climatology.—The disease is most commonly met with in West Africa, but has been reported from East Africa, Malaya, Sumatra, South China, and the West Indies. It usually affects native races, but has been reported in one European. Usually it begins in the first two decades of life.

Ætiology.—This is unknown, though the association with yaws gave rise to the suspicion that this was the ætiological factor. Cantlie's European, however, had not suffered from yaws, and monkeys do not suffer spontaneously from yaws.

Occasionally in yaws patients a bilateral or unilateral swelling of the nose is present (pseudo-goundou of Brumpt), but it quickly disappears along with the other symptoms of yaws under treatment with potassium iodide, which has no effect on true goundou.

Other theories have been that it was a racial trait, or that it was due to a larva of a fly, but these are certainly not correct. As far as we know, it is never congenital. Braddon thinks that it is a disease *sui generis*, and may be right.

Pathology.—Whatever the cause may be, there seems no reasonable doubt that the infection begins in the nose ; for although we were unable to find any abnormality in the nose of the cases we have seen, still, there was always a history of some obstruction, pain in the nose, and often of a bloody discharge. Moreover, Friedrichsen describes a swollen condition of nasal mucosa with almost polypoid excrescences. If this is correct, it is quite easy to understand that the vessels passing from the nose through the *sutura notha*, in the nasal process of the superior maxilla, can carry that infection to the periosteum, which, being irritated, proceeds to an excessive formation of bone in the area of that suture, a condition of affairs for which there is no very suitable pathological term, but which may be called a form of osteoplastic periostitis. This results in the formation of a bony swelling, composed on the outside of a thin shell of compact bone, underneath which is spongy, bony substance continuous with that of the bone from which it is arising. The *sutura notha* is, of course, found in all human skulls, and is not peculiar to the negro race.

The bony growths are attached to the nasal bone, the nasal process of the superior maxilla, and at times to the maxilla itself. The periosteum strips off readily, but usually shows no signs of recent inflammation.

Symptomatology.—Generally the disease begins with pain in the nose, or headache, which may be severe, and a bloody nasal discharge, which may continue for some six to eight months. When this is disappearing, it is noticed that there is a swelling, usually symmetrically placed on either side of the nose, in the region of the nasal bone and nasal process of the superior maxilla. Slowly and steadily these lumps increase in size, interfering with vision (it is said at times destroying the eyes), and giving rise to a hideous deformity rather like a *Cynocephalus* monkey, and hence called 'dog-nose.' When fairly well developed, an oval, bony swelling, with its long axis directed downwards and outwards, is seen symmetrically placed on each side of the nose; the skin over the tumour is never affected, being freely movable; and usually, when examined, the nasal mucosa is found to be normal, and the nasal ducts are patent, but there may be swelling and even polypoid-like excrescences. Occasionally a similar growth may invade the nose, partially blocking the nasal cavity. The growth, however, may stop at any stage of its development and proceed no farther. Some authors describe a curvature of the tibiæ as being associated with the disease.

Varieties. — Instead of being bilaterally symmetrical, the bony lump may develop only on one side of the nose. Orpen has described, in addition to the two usual tumours, a third in the malar region.

Treatment.—Medical treatment is useless, and removal is not merely easy, but most effective, as the disease is known not to have returned after some six or seven years after the operation.

Prophylaxis.—As the causation is doubtful, nothing can be said under this heading.

ENDEMIC ENLARGEMENT OF THE OS CALCIS.

Definition.—Endemic enlargement of the os calcis is a disease of unknown causation, characterized by fever, pain, and tenderness over, and subsequently enlargement of, the os calcis.

History and Climatology.—This disease was first described by MacLean in 1904 in Fantis and Krooboys in the Gold Coast Colony, and subsequently in 1905 by Maxwell in natives of Formosa.

Ætiology.—The ætiology and pathology are obscure, but in some way it is connected with the wet season, as attacks and recurrences take place then.

Symptomatology.—The disease begins suddenly with fever, great tenderness over the os calcis, with local pain so severe as to prevent sleeping and walking. In three to seven days the outer surface of the bone begins to increase in size, and continues to do so for some two weeks, during which time the pain lessens and the temperature falls to normal.

In about a month the swelling reaches its maximum size, at which it may remain for about one to two months, during which time the pain is moderate and walking is possible. After this the bone diminishes to about half the maximum size, but sometimes considerable enlargement persists. Usually the disease is bilaterally symmetrical, but it may occur on one side only. It affects the outer surface as a rule, but may also attack the posterior third of the bone.

Rarely it attacks other tarsal bones, but has never been reported as affecting a joint. Yearly recurrences during the wet season are common.

Treatment.—Medical treatment is useless, but relief is given by cutting down on to the affected area and trephining a hole into the bone.

Prophylaxis.—Concerning this nothing is known.

‘ MYCETOMA.’

Synonyms.—Madura-Foot, the Fungus Disease of India, Godfrey and Eyre's Tubercular Disease, Endemic Degeneration of the Bones of the Foot, Morbus Tuberculosis Pedis, Morbus Pedis Entophyticus, Podelkoma, La Maladie de Ballingall, Slipada, Hatty-ka-Pung, Keerenagrah (signifying a dwelling of worms), Kirudeo (signifying a dwelling of worms), Ghootloo Mahdee (signifying eggs of insects; probably so called from the small bodies found in the discharge).

Definition.—‘Mycetoma’ is a generic term for the invasion of the tissues of the foot and hand, and more rarely other parts of the body by fungi belonging to the genera *Discomyces*, *Aspergillus*, *Madurella*, *Oospora*, and *Indiella*, which produce enlargement, deformity, and destruction of the affected area.

History.—It is probable that mycetoma was known to ancient Indian writers on medicine, for references are found to a disease of the foot characterized by swellings like plum-stones, associated with a considerable amount of discharge, and thought to be due to injuries caused by thorns.

In 1712 Kaempfer drew attention to a disease of the foot, which he called 'perical,' or large foot, in natives of India. It is not very clear what he meant by this, as he may have confounded elephantiasis with mycetoma. In the early nineteenth century the disease was well known in the South of India, where it was called 'Madura-foot,' being described by Heyne in 1806, and mentioned in Brett's 'Surgery,' in 1840 as a distinct disease. In 1842 Gill appears to have been the first to clearly differentiate it, and he was followed by Godfrey in 1844 and 1846, Morehead in 1846, Colebrook in 1848; but many of these early writers appear to have considered the disease to be tubercular.

Ballingall, in 1855, was the first to state that it was probably of parasitic origin, and he was followed by Rustomji, who gave careful clinical histories of eight cases.

In 1860 Eyre gave an account of the disease, and V. Carter published the first of a series of most important papers extending till 1874, in which he studied the whole subject most minutely, and found the causal agent to be a fungus. In 1859 he discovered the fungus of the melanoid or black variety, now called *Madurella mycetomi* Laveran 1902, and later, in the same year, he found the fungus of the ochroid, or white variety, which is at the present time called *Discomyces maduræ* Vincent 1894. He was followed by a large number of observers, among whom may be mentioned H. J. Carter, who in 1862 described a fungus belonging to the Mucoridæ, which Berkeley in 1865 called *Chionyphe carteri;* but their methods of separating and growing this fungus were crude, and there is no doubt that it was a contaminative fungus. Lewis and Cunningham in 1875 did not believe in the fungoid origin, and ascribed the disease to degenerations; and in 1876 Kemper and Jamieson described a curious case of foot disease under the term 'podelcoma' as occurring in America. It is probable that this may have been a case of mycetoma, but if so, it was remarkably acute in its course. Bassini in 1888 described an undoubted case in Italy, and Wright a similar case in an Italian in America. In 1892 Kanthack and Hewlett independently studied the pathology of the disease, and concluded that it was really an actinomycosis. In 1893 Boyce and Surveyor examined a number of cases and grew the fungus artificially. In 1894 Vincent published an account of a case of the white variety occurring in Algeria. He cultivated the parasite, and inoculated it without success into animals, and finally named the variety *Streptothrix maduræ,* thus clearly differentiating one variety of the disease.

In 1895 Adami and Kirkpatrick published an account of the first undoubted case in Canada, and later similar cases were reported in other parts of America; and in 1897 Unna studied the pathology of the disease. In 1901-02 Bouffard described black and white varieties of the disease as occurring in Somaliland.

In 1902 Laveran investigated Carter's black variety, and named it *Streptothrix mycetomi;* and Foulerton and Jones published a paper on the pathogenesis of the Streptothrix group. Nicolle and Brunswic-le-Bihan described a case of white mycetoma in Tunis, caused by *Aspergillus nidulans* cultivated by Nicolle and Pinoy. The fungus was introduced into the foot by a grain of barley. In 1906 Brumpt published a most valuable paper showing that actinomycosis was the cause of one variety of mycetoma, and that Carter's, Vincent's, Nicolle's, and Bouffard's white and black mycetomata were all separate varieties of the disease caused by distinct fungi, and in addition, he described two other varieties, making a total of eight varieties due to separate fungi. In 1907 Musgrave and Clegg described a new form o the disease in the Philippine Islands, due to *Streptothrix freeri,* which they successfully inoculated into the foot of a monkey. This fungus they now consider to be identical with *D. asteroïdes.*

Climatology.—The disease is diffused throughout the world, being known in Asia, Africa, Europe, and America, but is far more com monly met with in the tropics than in the temperate zone, and is especially prevalent in India, particularly in the Madras Presidency about Madura, Bellary, Tanjore, and Trichinopoli.

In Asia it is known in India, not merely in Madras, but also in Cochin, Pondicherry, Sind, Cutch, Bengal, Rajputana, the North-West Provinces, the Punjaub, and Kashmir. It also occurs in Ceylon and Aden. In Africa it is also widespread, being met with in Madagascar, Somaliland, Abyssinia, Jibuti, the Sudan, Egypt, Algeria, Morocco, and Senegambia. In Europe it is rarely met with, but cases have been reported from Cyprus, Italy, and France. In America it has been reported as occurring in Canada, the United States, Nicaragua, the West Indies, Argentina, and Chili.

With regard to the known distribution of the varieties, the actinomyotic has only been reported from Madagascar; Porter's black mycetoma from India, Italy, and Senegambia; Carter's ochroid variety from India, Somaliland, Abyssinia, Algeria, Cyprus, Cuba, and Argentina; Bouffard's black and white varieties from Somaliland; Brumpt's white variety from India; Reynier's white variety from Paris; and Musgrave and Clegg's from the Philippine Islands. It is not definitely known what influence the season of the year has on the occurrence of the fungus, though probably when the saprophytic history is known some such influence may be discovered.

Ætiology.—The disease is due to the entry of a fungus into the subcutaneous tissue of some part of the body by means of a wound.

The region invaded is usually the foot, more rarely the hand, and still more rarely some other region.

The causal fungi may be classified as follows:

Order.	Genus.	Species.
Ascomycetes	Aspergillus	A. nidulans Eidam 1883. A. bouffardi Brumpt 1906.
	Oospora	O. tozenri Nicolle and Pinoy 1908.
Hyphomycetes	Discomyces	D. bovis Harz 1877. D. maduræ Vincent 1894. D. asteroïdes Eppinger 1890.
	Madurella	M. mycetomi Laveran 1902.
	Indiella	I. mansoni Brumpt 1906. I. reynieri Brumpt 1906. I. somaliensis Brumpt 1906.

The saprophytic life of these parasites is quite unknown, with the sole exception of *Discomyces bovis*, which lives in the spikelets of various cereals.

The disease occurs most commonly in people who walk barefoot, and is therefore most usually met with in native races, though race *per se* has no predisposing influence. It is principally found in agricultural labourers, and is therefore more common in the poorer classes and in males.

Pathology.—The causal fungus is introduced into some part of the body by a wound produced by a thorn, a splinter of bamboo or other wood, by a sharp stone, knife, etc., but perhaps the most interesting recorded case is Vincent's Tunis case, in which the disease was started by an injury to the foot by a grain of barley. Once introduced into the subcutaneous tissues, it commences to grow, the original wound in the meantime healing. Usually the growth is slow; but if Kemper and Jamieson's case was true mycetoma, it may be rapid, and, indeed, this is supported by Musgrave and Clegg's inoculation of *Discomyces asteroïdes* into monkey's feet, in which the swelling developed in ten to sixteen days, and was quickly followed by suppurative lesions. As the fungus grows it destroys the tissues of the foot, and meets with but little reaction on the part of the body, and no attempt is made to repair its ravages. The reaction on the part of the body confines itself to a lymphocytic infiltration around the fungus, and later the formation of granulation tissue, with epithelioid and giant cells at times; while, finally, fibrous tissue is formed around the fungus and its surrounding cells, and the vessels become blocked by an endarteritis and periarteritis. This appears to be an attempt to encapsule and prevent the spread of the parasite, as well as to damage it by cutting off its food-supply.

At the same time the cellular exudate becomes a thin, oily, often stinking, pus, and works its way to the surface, forming apertures and carrying the parasite with it. This must be considered to be an attempt to rid the body of the fungus.

In the meanwhile the parasite forms special club-shaped hyphal chlamydospores, which at first serve for extracting nutrition from the surrounding leucocytes, but later, breaking free from the main mass, form means of asexually propagating the fungus in the foot. Some of these separated clubs are attacked and engulfed by leucocytes, and though it is possible that in this way many may be destroyed, still, Brumpt's researches show that the leucocyte, with its enclosed club, may wander away from the diseased area into healthy tissue, and may be killed by the club, which, being set free, grows into a new mass of fungus. In this way the fungus may be disseminated by means of the phagocytes.

When surrounded by pus, the fungus gathers itself into granules, the so-called sclerotia, which show externally radially arranged fibres or clubs, and internally a mass of mycelium with crystals and débris, the latter being most marked in the centre. These granules escape to the exterior, and form the yellow, black, or pink granules in the discharge. As the fungus grows in the foot the connective tissues and the muscles undergo vitreous degeneration, and break up into débris, amongst which pieces of nerves and tendons may be found, while even the bone in some cases becomes attacked by a form of degeneration and disappears. The result is that the foot appears much swollen externally, and shows the openings of the sinuses, through which the pus and the fungoid granules escape; while internally the normal structure may have completely disappeared, being replaced by degenerated tissue, débris, sinuses, and fibrous sacs containing the fungus and the pus.

The result is, however, not merely destruction of the foot, but also great bodily waste, due to the continuous discharge, so that the patient becomes emaciated, and may finally die of asthenia Very rarely do the fungi invade the body, as is the case with *Discomyces bovis*, which may give rise to a general infection.

The peculiarity of the pathology is the slight reaction which the body makes against the invasion by the fungus, and the entire absence of any attempt at repair.

The black varieties of mycetoma owe their colour to a dark substance which they secrete. The nature of this black substance is not known. It is soluble in hot sulphuric acid, forming a yellowish-red solution, but is not soluble in cold sulphuric acid nor in potash solutions.

According to Thudichum, it does not contain hæmoglobin in any form, though a small quantity of iron is present. The nature of the yellow pigment does not appear to have been investigated, though Musgrave and Clegg remark, with regard to *Discomyces asteroïdes*, that a pigment of the appearance of hæmoglobin may be seen.

Morbid Anatomy.—Externally the swollen foot shows nodules and openings, the latter of which lead into the sinuses. In sectionizing the foot it will be noticed that the sinuses run in various directions, and end in small cavities containing pus and the fungus, and that these cavities are embedded in degenerated tissue and débris.

The bone may or may not be affected, but if it is, the whole foot can be easily cut by a knife.

Microscopically the tissues simply show degeneration and débris, with fibrous tissue formation, endarteritis, and periarteritis, and at times absorption of the bone. Inside the fibrous capsules will be found pus cells and the fungoid mass, consisting externally of clubs or radiate hyphæ mixed with leucocytes, and internally of a mycelial mass.

Symptomatology.—The disease usually begins in the foot, more rarely in the hand, and still more rarely in the leg, knee, neck, or trunk. There may or may not be a history of a cut or injury some time previously. In any case this primary injury will have healed long before the disease is well established.

The incubation period in well-recorded cases would appear to be short; thus, in Musgrave and Clegg's case, one month after the primary injury the wound reopened and discharged pus, and in their experiments on monkeys it appeared to vary from ten to sixteen days. Further researches on this point are, however, required.

The earliest signs are either pain or swelling in the region of the original injury, which is usually on the sole of the foot, between the toes, or on the instep. The swelling becomes a hard lump, on the surface of which a bleb may form, which bursts and reveals a small opening discharging an oily, rarely sanious, thin, offensive pus, in which the granules characteristic of the fungus may be found.

Soon new indurations and nodosities appear in various parts of the foot, and new openings are formed, while the whole foot begins to swell in a very characteristic manner. First the arch of the foot fills up and disappears, the whole sole becoming so swollen and convex that the toes are no longer able to touch the ground, and may be pushed apart, but are usually not affected by the disease. At the same time the dorsum of the foot becomes studded with nodules and openings. The colour of the integument may be normal, but is usually darker than in the healthy foot. It is rarely œdematous. The openings, when examined by a probe, are found to lead into sinuses, which penetrate deeply into the tissues, and at times even into the bones of the foot. The quantity of the discharge varies from time to time, being increased by motion. On palpating the affected area, it is found to be elastic, and the sensibility to be normal.

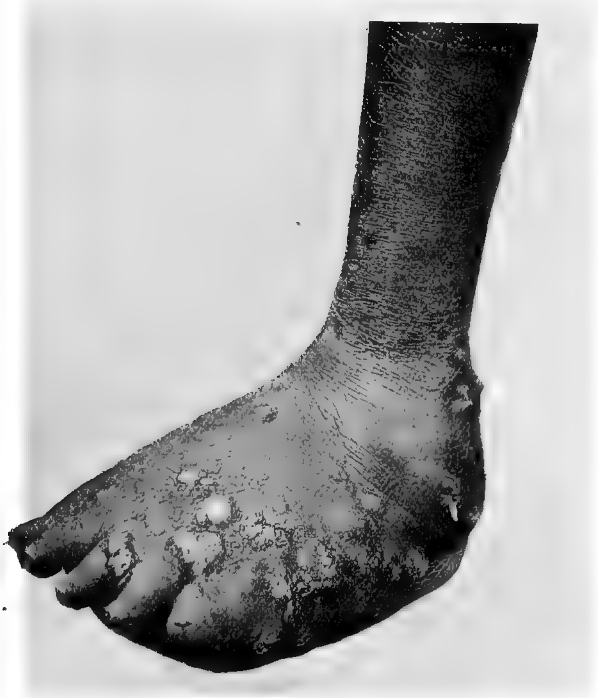


Fig. 348.—Mycetoma.

As the disease progresses, pain, which at first was slight, becomes more marked, especially in cold weather. The patient ceases to be able to place the foot to the ground, and is compelled either to walk on the heel or to use a support. The leg begins to waste, and after a long time the patient becomes weak and anæmic from the constant drain on the system, but general constitutional disturbance of a febrile nature is rare.

The disease is very chronic, and has no tendency to heal, and if not treated, will eventually cause the death of the victim, from exhaustion or diarrhœa, after lasting some ten or twelve years.

Varieties.—The disease can be classified by the different causal fungi into nine varieties, which may be arranged, according to the colour of the granules or sclerotia, into the black or melanoid group, and the white or ochroid group, as follows:

A. THE MELANOID GROUP.

1. Carter's black mycetoma.
2. Bouffard's black mycetoma.
3. Nicolle and Pinoy's black mycetoma.

B. THE OCHROID GROUP.

4. Carter's white mycetoma.
5. The actinomycotic white mycetoma.
6. Nicolle's white mycetoma.
7. Brumpt's white mycetoma.
8. Reynier's white mycetoma.
9. Bouffard's white mycetoma.
10. Musgrave and Clegg's white mycetoma.

A red variety has been described in Africa due to *Penicillium bouffardi* Brumpt 1906, but has not so far been completely investigated.

1. *Carter's Black Mycetoma.*—The sclerotia are hard, irregular, brittle, black or dark brown in colour, 1 to 2 millimetres in diameter. The hyphæ are white, but the interhyphal substance is dark brown. This is the type of the disease, and is caused by *Madurella mycetomi* (Laveran) 1902.

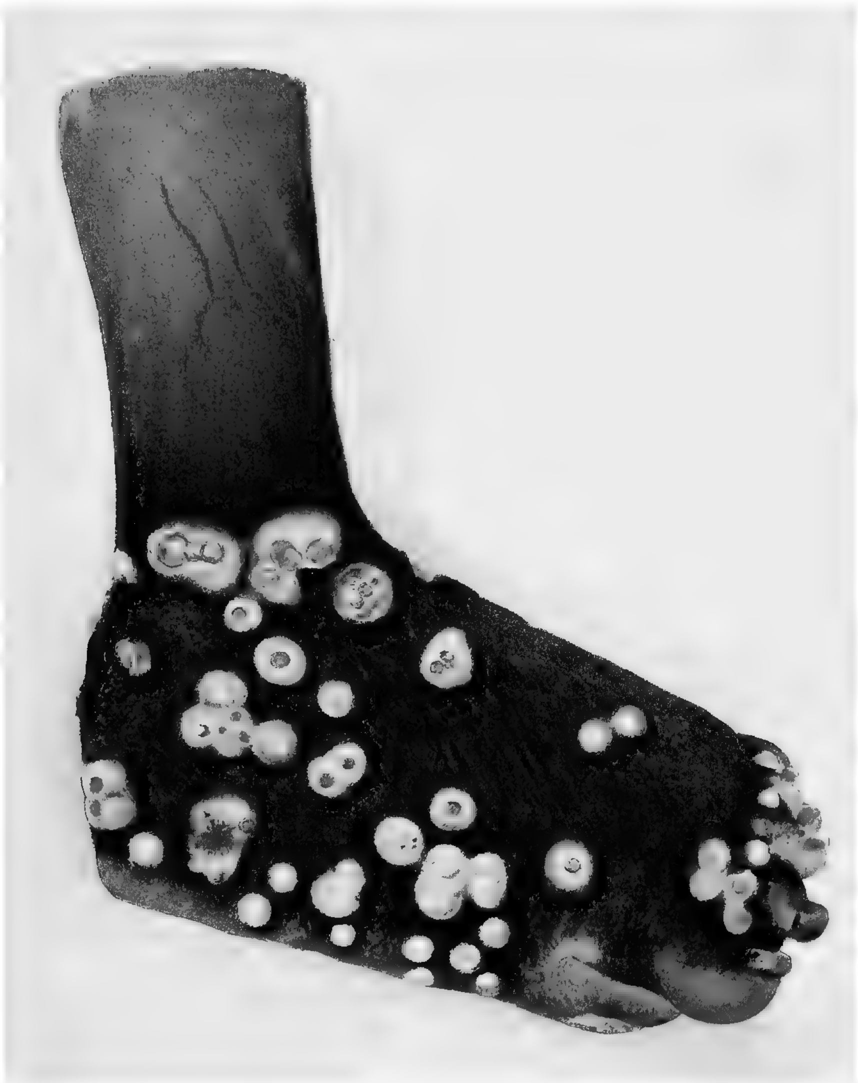
2. *Bouffard's Black Mycetoma.*—The sclerotia are moriform, elastic, and vary in size from a pin's head to a small pea. The grains are contained in giant cells. The disease, which is readily amenable to treatment by curetting, is caused by *Aspergillus bouffardi* Brumpt 1906.

3. *Nicolle and Pinoy's Black Mycetoma.*—The sclerotia are hard, small, and black. During parasitic life the mycelium is septate, 1 to 4 microns in breadth. Chlamydospores are present. It is found in Algeria and Tunis.

4. *Carter's White Mycetoma.*—The sclerotia are yellowish-white, mulberry-like, spherical grains, varying in size from minute pinheads to peas. It is caused by *Discomyces maduræ* (Vincent) 1894.

5. *Actinomycotic White Mycetoma.*—The sclerotia are yellowish and soft. The disease destroys the bones, and can spread throughout the body, forming metastases in distant organs. The causal fungus is *Discomyces bovis* (Harz) 1877.

PLATE VI.



MYCETOMA.

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6. *Nicolle's White Mycetoma.*—The sclerotia are large, rounded, and smooth, like peas. It attacks the bones. The causal fungus is *Aspergillus nidulans* (Eidam) 1883.

7. *Brumpt's White Mycetoma.*—The sclerotia are very small, hard, and bean-shaped. The fungus in the foot lacks the connective-tissue sheath normally present. The causal fungus is *Indiella mansoni* Brumpt 1906.

8. *Reynier's White Mycetoma.*—The sclerotia are very large, soft, coiled masses. It is due to *Indiella reynieri* Brumpt 1906.

9. *Bouffard's White Mycetoma.*—The sclerotia are large, spherical or polyhedral grains, sometimes white, sometimes reddish-yellow in colour. It destroys bone. It is caused by *Indiella somaliensis* Brumpt 1906.

10. *Musgrave and Clegg's White Mycetoma.*—The sclerotia vary in size from 0·25 to 5 millimetres. Oval at first, they become various shaped when full-grown. The fungus which invades the medulla of the bone is *Discomyces asteroïdes* Eppinger 1890.

Diagnosis.—The peculiar swelling of the foot, with a filling-up of the arch, and the formation of sinuses from which a discharge containing the typical sclerotia is escaping, enables the disease to be diagnosed with certainty from elephantiasis or tubercular disease of the foot.

The variety of the fungus may be determined by examining the grains or the scrapings of the sinuses microscopically, culturally, and by inoculations in animals.

Prognosis.—The disease is incurable unless treated surgically.

Treatment.—The diseased area, if localized, may be removed by curetting or excision; but if a large area of the foot is affected amputation must be performed well above the boundary of the disease.

Prophylaxis.—Prophylaxis consists in guarding against wounds from pieces of wood, stones, etc., by wearing boots, shoes, or sandals. Should a wound occur, it must be thoroughly cleaned with antiseptic lotions before being allowed to heal.

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CHAPTER LIII

NERVOUS DISEASES

General remarks—Endemic paralytic vertigo—Lâtah—Schamanismus—Âmok—Tropical neurasthenia—Endemic peripheral neuritis—Erythromelalgia tropica—Desert hallucinations—References.

GENERAL REMARKS.

THE nerve diseases of the tropics include many general diseases already dealt with—*e.g.*, pellagra, malaria, leprosy, beri-beri, etc. But apart from these conditions, meningitis, cerebral tumours, cerebral hæmorrhages, spastic paralysis, alcoholic neuritis, and, more rarely, arsenical neuritis, are all well known. Locomotor ataxia and general paralysis—the so-called parasyphilitic affections—are rare, though syphilis is rampant. The cerebral tumours which we have most commonly met with are endotheliomata and tubercular or syphilitic lesions. Hysteria is common among the better-class natives, especially among the young women educated according to Western ideas.

As regards insanity, mania and melancholia are the most usual; but dementia, idiocy, and epileptic insanity are not uncommon. According to Dr. Spence, Superintendent of the Asylum at Colombo, the burden of lunacy in Ceylon is light as compared with England, Scotland, or Ireland, and it is possible that this applies not merely to Ceylon, but to other countries. But apart from these diseases, there are some curious nerve or mind affections which must be considered at greater length.

Tropical 'kohler' has already been mentioned (p. 65), but tropical neurasthenia must be dealt with.

ENDEMIC PARALYTIC VERTIGO.

Synonyms.—Vertige Paralysant, Vertige Ptosique, Gerlier's Disease, Kubisagari, Tourniquet.

Definition.—Endemic paralytic vertigo is characterized by eye symptoms, such as ptosis, dimness of vision, and by paralysis of the neck and extremities.

History.—The disease was first described by Gerlier in Ferney, in Switzerland, in 1886, and by Miura, in 1894, in Japan.

Climatology.—It is known in France, Switzerland, and Japan, where it is found in the northern provinces and in the island of Shikoku.

Ætiology.—The ætiology is entirely unknown, and hence there are many theories, which suggest alcohol, poisoned bread and lentils, and latent malaria ; but the one which is favoured by both Gerlier and Miura is the association of the disease with stables. Gerlier says that in the valley of the Lake of Geneva it is not unusual for people to sleep in the stables ; and Miura says that in the regions affected in Japan it is usual to have the house so arranged that a part is used as a stable, while the remainder is occupied by the family.

Further, it is associated with warm weather. Miura gives as exciting causes bodily exertion while hungry or after a full meal, writing, reading, steady attention to anything, uniform movements or mixing with crowds ; while the attacks are diminished by rest and change.

Pathology.—This is quite unknown.

Symptomatology.—An attack begins with a blurring of objects, everything appearing as if in a fog, together with ptosis, and, less frequently, a diplopia due to paralysis of the internal rectus, with sometimes photophobia, disturbances of colour vision, and hyperæmia of the optic disc. Then follow disturbances of speech and loss of power in mastication, and, in bad cases, of deglutition. At the same time paralysis of the muscles of the back of the neck, the back, and the extremities are observed. The head falls forward, and is only raised with difficulty ; hence the name of the disease, 'kubisagari,' which means 'he who hangs his head.' If the muscles of the back are paralyzed, there may be difficulty in raising the body from a stooping posture. Weakness in the hands, arms, and legs is often observed, and is first noticed in the muscles connected with symmetrical repeated movements. An attack lasts from ten to fifteen minutes, and varies in severity, in mild cases there being only ptosis and dimness of vision. Between the attacks the patient is perfectly well in every respect. After severe attacks there may be a little ptosis, or weakness of the muscles of the back, neck, hands, or legs, and increased reflexes.

Prognosis.—The disease is never fatal, though it may last for many years.

Treatment.—The first requirement is removal from the endemic area and from living in close proximity to stables. Medicines are not of much use, but a combination of potassium iodide and arsenic is recommended.

LÂTAH.

Synonym.—Mimicismus.

Definition.—Lâtah is a mental condition in which suggestion is at once followed by uncontrollable action of which the mind has no knowledge.

Climatology.—Lâtah is found principally in the Malay Peninsula, Java, Sumatra, and is also known in Siam, in Burma, in the Philippines, Siberia, and among the Jumpers of North America. Fletcher has rightly drawn attention to the fact that, while the disease is very common in the Malay States, it is, apparently, rare in the Malays who have emigrated. Thus, for example, it does not occur among the large colony of Malays in Ceylon, which may be due to the fact that they originally came from Batavia in Java, and not from Malaya, but it is said by Fletcher to occur in Chinese, Tamils, and in Europeans living in Malaya. The Ikota or Samoyeds and the Tigretier of Abyssinia, are said to suffer from similar symptoms. In children the disease is milder than in adults.

The exciting cause appears to be any sudden start, producing some peculiar movement, after which any unlooked-for action may be imitated, and is generally accompanied by bad language. The mildest form of the disease is merely an exclamation or a scream when startled, but in severe cases the patient will imitate any sudden motion or obey any suggestion made to him.

Fletcher relates that in some parts of the Malay States it is occasionally impossible for a judge to examine the witnesses, as they can do nothing but imitate and repeat the questions put to them.

The most graphic account of the symptomatology of the fully developed complaint is that given by Sir Hugh Clifford in his 'Brown Humanity,' from which we are kindly permitted to give an extract. The disease is best seen in the Malays, and no white man knows these people as Sir Hugh Clifford knows them, and therefore the following is of peculiar value :

> 'The most typical case of lâtah within my experience was that of a Selangor Malay named Sat, who, in 1887 and 1888, cooked the rice for me and for ten, twenty, or thirty Malays who were then living in my house at Pekai. He was a great big, heavy-featured, large-boned, clumsily-built fellow, very solid, very stupid, very phlegmatic—the last person in the world one would have thought to be the victim of any nervous disorder. To the lay mind any abnormal degree of sensitiveness should be accompanied by a somewhat ethereal physique, a delicate skin, a blue-veined forehead, tiny hands and feet, and a highly strung organization. To none of these things could poor Sat lay any sort of claim; and though, no doubt, doctors will say that these are by no means invariable accompaniments of a highly nervous temperament, I must own that Sat looked vastly improbable as the possessor of anything so rarefied. All the other Malays in my household were accustomed to put upon Sat most unmercifully, making him do almost the whole of the work that should rightly have been shared between them all. Sat never appeared to resent this arrangement, and he never made any complaint to me then, or at any later time, of the manner in which his fellows treated him.
>
> 'He spent almost the whole of his day in the great ramshackle room, built out over the river on supporting piles of nibong, in which the large wooden box, filled with baked clay, which served as our simple cooking-range, occupied the chief place in the centre of the tala floor.
>
> 'When the others were most noisy, Sat was still silent. When some of my men boasted of the great deeds they had performed in the old days in Selangor, Sat would listen obediently to the thrice-told tales, stolidly, but without excitement. Most of the other men had their own particular chums,

but Sat was always solitary, and he never appeared to have any ideas in that great bullet-head of his which he desired to exchange with his neighbours.

'He had been an inmate of my hut for nearly a year before anyone discovered that he was lâtah. The fact came to light quite accidentally, Sat being startled out of his self-possession by the sudden capsizing of a cooking-pot over which he was watching. A boy who chanced to be alone in the cook-room with Sat made an instantaneous grab at the fallen rice-pot, and in an instant Sat's hand was in the fire, grasping the burning hot metal. He withdrew his flayed fingers quickly, as the pain brought to him consciousness of what he had done, and he carried them at once to his head—that queer, groping, scratching motion which is an invariable accompaniment of lâtah—and the boy at his side needed no man to tell him that Sat was a victim to that extraordinary affliction.

'With the wanton cruelty and mischief of his age, the boy once more made a feint at the smoking rice-pot, and again Sat's fingers glued themselves for a moment to the scalding metal, and returned aimlessly to his head.

'I do not know how many times this was repeated, but Sat's fingers were in a terribly lacerated condition when at last someone chanced to enter the cook-room, and interfered to prevent the continuation of Sat's torture.

'After that, though I did all I could to protect him from molestation, Sat was never, I fancy, left in peace for long by the other men of my household. Gradually, in the course of a couple of months or so, this man, who for nearly a year had shown no signs of being the victim of any nervous disorder, was reduced to a really pitiable condition. The occasional lâtah seizures, which were at first induced by the persecutions of his fellows, ceased to be abnormal phases, and became the chronic condition of his mind. If one spoke to him, with no matter how much gentleness, he would repeat the words addressed to him over and over again, aimlessly, unintelligently, without, apparently, comprehending their meaning, and that wandering, groping hand of his would steal to his head, and scratch helplessly at his close-cropped hair.

'"Sat, listen, Sat!" I would say to him as quietly and as reassuringly as I knew how. "Listen! no man is worrying thee. Try to listen to what I say to thee." Sat would make answer, and then, very low, in a whisper under his breath: "Listen, listen, listen, listen, listen what I say to thee."

'I instituted a fine for anyone who was found annoying Sat, but it was impossible to get a conviction, for the unfortunate victim could never say who the man was who had teased him into a more than usually severe paroxysm of lâtah.

'It was about this time that a number of other people in my household began to develop signs of the affliction. I must not be understood as suggesting that they became infected with lâtah, for on inquiring, I found that they had one and all been subject to occasional seizures when anything chanced to startle them badly long before they joined my people; but the presence of so complete a slave to the affliction as poor Sat seemed to cause them to lose the control which they had hitherto contrived to exercise over themselves. One of the older men among my people—Pa'Chim, we called him—a Malay by birth, and of some standing with his fellows, came to me and begged that I would see that no one did anything to give him a sudden start, since, he said, only a very little was needed to make him lâtah also. Yet this man, neither then nor later, showed any signs of the affliction. He probably exercised a considerable amount of self-control, but I always knew that in a moment I could have broken through his guard, and have startled him into as complete a seizure of lâtah as those of which Sat was the victim.

'One day a curious thing happened, which I will relate as it occurred, though I only witnessed the end of the incident.

'A Trĕnggânu Malay, who had a cousin among my people, came in to visit his relative, and chanced to find no one but Sat in the house. The latter invited the Trĕnggânu man to partake of sîrih, and they squatted down on the pêntas, or raised eating-platform, in the centre of the house, with the sîrih-box between them. The villainous small boy who had first discovered Sat's weakness was playing about in the room, and in some unholy way he had learned that the Trĕnggânu visitor was also a lâtah subject. He seized a long rattan, which, I think, was kept in the room by one of the older men for his occasional correction, and smote the sîrih-box as it lay between the two betel-chewers, making the wooden covering resound with the smart blow. The sudden and unexpected noise at once deprived both men of all power of self-restraint. Each gave a sharp cry and a "jump"—to use the colloquial expression—and, since there was nothing to distract their attention from one another, they fell to imitating each the other's gestures. For nearly half an hour, so far as I could judge from what I learned later, these two men sat opposite to one another, gesticulating wildly and aimlessly, using the most filthy language, and rocking their bodies to and fro. They never took their eyes off one another for sufficient time for the strange influence to be broken, and at length, utterly worn out and exhausted, first Sat and then the Trĕnggânu man fell over on the platform in fits, foaming horribly at the mouth with thin, white flakes of foam. Men came running to me for help, many having witnessed the end of this strange scene, and when I had doctored Sat and his companion back to consciousness, I tried to ascertain from them how they had come to fall victims to this seizure. They could tell me nothing, however, for they only remembered that before their trouble came upon them they had been chewing betel-nut. The matter was sifted out, none the less, and the small boy who had been the cause of the trouble again made the acquaintance of the piece of rattan, and, to judge by his cries, found the interview an unusually painful one.'

From the above account it will be seen that a sudden action will inhibit the higher centres and produce reflex movements in imitation of those performed by the exciting cause. The loss of memory of what has taken place and the peculiar movement of the hand to the head indicates the abrogation of the higher powers.

Lâtah must be closely related to those curious psychical phenomena, seen at times among different races, the afflicted people being variously known in Europe as 'the Jumpers,' 'the Barkers,' and 'the Jerks,' and must also be allied to those states of excitement into which people pass during times of religious revivals. In our experience it has also a certain resemblance to some cases of so-called 'Maladie de Gilles de la Tourette,' the main symptoms of which are acholalia and coprolalia.

A peculiar psychical outbreak took place in Madagascar in the years 1863-64 among the women of the lowest classes, consequent on the profound sensations caused by the violent death of King Ramada II., and the subsequent changes in the religion and laws. This outbreak is said to have been identical with the dancing mania of the Middle Ages. It is interesting to remember that there is a strong admixture of Malay blood in the natives of Madagascar, especially in the ruling classes.

It is thus seen that the condition, though at present most marked among the Malays, is, and has been, world-wide in its spread, and is really due to the possession of feeble higher centres which are easily upset, and then are unable to control the lower centres in the accustomed manner.

With regard to the medico-legal aspect of lâtah, Fletcher has recently performed an experiment with a severely affected subject, proving that suggestion can compel a lâtah subject to commit a crime even against his will. He concludes that in lâtah crime is a possibility either as—

1. An act resulting from an imperfectly controlled inco-ordinate reaction to a sudden impulse ; or as

2. An act resulting from the suppression of volition in the severe forms, the determining cause of which is a criminal suggestion by a second person.

In evidence of the first, he cites two Malays going through a forest carrying their knives for cutting wood. A twig suddenly snaps, and the first man falls to the ground, which so upsets the second one that he also falls to the ground, and in so doing accidentally wounds the first man with the knife he is carrying. In evidence of the second, he places a dummy in a bed previously occupied by a friend of a lâtah person who had been removed without the latter's knowledge. Suddenly the lâtah person was ordered to take a knife which was placed in a handy position, and stab the dummy in the bed. The lâtah person tried not to do this, but was compelled to obey the suggestion. Thus, it would appear that there may be a near connection between lâtah and crime.

SCHAMANISMUS.

Schamanismus is the condition of excitement into which certain persons of the Dayaks and other peoples are able to throw themselves for religious purposes. This state of excitement seems to be attained by leading an extremely erotic life, and appears, by its singing, shrieking, and dancing to utter weariness, to resemble the dancing mania of the Middle Ages, and, therefore, to be related to lâtah.

ÂMOK.

Definition.—Âmok is a psychical disturbance, which, after a period of depression, suddenly develops into a violent attempt to kill people, of which no memory may be left, and after which a stuporous condition supervenes.

Âmok, which means 'an impulse to murder,' is a disease frequently found among the Malays. The exciting cause appears to be a strong emotion of anger, sorrow, or fear, after which a pause or incubation period of depression follows, which may last for days or weeks, during which the patient broods over his wrongs. The attack is ushered in by colour sensations of red or black, with or without vertigo, and the patient complains of the appearance of devils, which they attempt to kill. The attack usually lasts but a short time, and the deeds performed during that period are not remembered. After the attack, the patient passes into a stuporous condition or deep sleep, which may last for a long time, after which he remains in a peculiar excitable condition for some months.

This is a curious pathological entity, and may be a genuine psychical obliquity closely related to those epileptoid seizures investigated in Europe by Lombroso.

If a case is considered genuine, the patient must not be regarded as responsible for his actions, but each case should be judged on its own merits.

TROPICAL NEURASTHENIA.

No disease among Europeans in the tropics deserves more careful study by the practitioner than neurasthenia, because, though not in itself fatal, still it leads to many of the petty worries felt and bad tempers exhibited, and, in worse cases, may seriously hamper good work being performed. The subject has recently been ably studied by Fales in Americans returning from the Philippine Islands.

Ætiology.—Tropical neurasthenia is apt to develop in white people in any part of the tropics, but especially in those which are subject to moist heat, and in some cases an important predisposing cause is the sun's rays, the effects of which are often disregarded. Moreover, the white man is generally compelled to work hard throughout the heat of the day, and is often exposed to the midday sun. The liability to the disease increases with the length of residence in the tropics. Predisposing causes are any previous illness, alcoholism, and overwork. Fales states that he found 30 per cent. of the men and 50 per cent. of the women who had resided for a year or longer in the Philippine Islands the subjects of such severe neurasthenia as to be semi-invalids. In our experience the disease is extremely common all over the tropics in Europeans as well as in the natives of the educated class.

Symptomatology.—In addition to the ordinary signs of neurasthenia, the tropical form seems to markedly affect the vascular system; palpitation is very common, and the patients suffer from various kinds of phobia, especially relating to diseases of the tropics.

Treatment.—The best treatment is rest and change of climate and mild hydropathic treatment. If this is not possible, hypodermic injections of sodium glycero-phosphate—0·1 gramme daily in bad cases—or some form of glycero-phosphate, with or without polyformates, by the mouth in mild cases, may be tried. The patient should discontinue cold baths, and should use warm baths, which should be taken at night if there is sleeplessness. Bromides are occasionally useful.

Prophylaxis.—As in some cases the disease is predisposed by exposure to the sun, protection is required against the sun's rays by topees lined with red, and, if necessary, by red underclothing or clothes made from the 'solaro' fabric already mentioned, and by avoidance of the midday sun as much as possible, and the total abstinence from alcohol.

In persons who are compelled to work hard under unfavourable conditions, change to the temperate zone at relatively short intervals—*i.e.*, about once in two or three years—is most necessary.

ENDEMIC PERIPHERAL NEURITIS.

Synonym.—Akatama.

Definition.—Endemic peripheral neuritis is a disease of unknown origin, characterized by numbness and intense prickling and burning sensations in the presence of cold or damp, which are temporarily relieved by the application of dry heat.

History.—The disease was first noticed by Wellman in Central Africa in 1896, and described by him in 1903. It affects 3 to 5 per cent. of the Bantu people, who are by profession porters, and are much impeded in their work by this complaint, which affects young and old, male and female alike. Their staple food is maize, which is eaten partially cooked.

Climatology.—The disease is found in that plateau of Africa which is 5,000 to 6,000 feet high, and is situated between 13° to 14° south latitude, and is inhabited by the Bihé, Bailundo, and Andulu peoples, all of whom are Bantus.

Ætiology.—Wellman was unable to find any causative organism in the blood or fæces. Some of the natives also suffered from filariasis, agchylostomiasis, and bilharziosis, but these were adventitious. His theories are that it may be caused by cold, fermented maize, or nerve-starvation ; but he is not satisfied with any of these hypotheses.

Morbid Anatomy.—In bad cases there is some swelling, erythema, and slight œdema of the affected part ; still, biopsies of the skin revealed nothing, and post mortem the nerves were found normal.

Symptomatology.—The disease usually begins with shooting, pricking, or crawling pains in the legs and forearms, accompanied by numbness, together with an erythematous rash and swelling of the affected area. All these symptoms are increased by cold and damp, and diminished by heat and dryness. They may also appear on the thighs and arms, and occasionally on any part of, or all over, the body. The gait is peculiar, the patient appearing to walk on the toes and heels. The disease may last for years, but spontaneous recovery is known.

Diagnosis.—The diagnosis is easy, for it is distinguished from beri-beri by the absence of pain in the calves, by the absence of the heart symptoms, and of the paralysis ; from elephantiasis by the swelling being transitory ; and from malaria by an examination of the blood.

Prognosis.—This is good as to life and general health, though the course of the malady may be very protracted.

Treatment.—No method of treatment is known to do any good.

ERYTHROMELALGIA TROPICA.

Under this term Gerrard describes a nerve condition in which natives who work barefoot on roads and plantations in Malaya complain of a feeling of pins and needles in the soles of the feet, followed by an acute burning sensation, which prevents walking and sleeping. Malaria is assigned to be the cause. The treatment recommended is to place the feet in hot salt-water, which is said to give great relief.

DESERT HALLUCINATIONS.

Synonym.—La Ragle.

D'Escayrac de Lauture describes hallucinations of the senses of sight, hearing, smell, or taste, or even of common sensations, which attack persons suffering from exhaustion in deserts. The causation is probably inanition. Generally the attack comes on at night, but it may occur in the day-time, when it is considered to be more serious. Usually hallucinations are visual, and thus stones look like buildings or large rocks, while caravans or files of soldiers may be seen which do not exist. It has nothing to do with true mirage.

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CHAPTER LIV

SKIN DISEASES: PYOGENIC INFECTIONS

Pemphigus contagiosus—Pyosis tropica—Purulent folliculitis of the legs—Pyosis palmaris—Dermatitis rimosa—Dermatitis bullosa plantaris—Veldt sore—References.

PEMPHIGUS CONTAGIOSUS.

Historical and Geographical.—This dermatosis was first described by Manson. It is very common during the hot season in China, the Malay Peninsula, Ceylon, and Southern India, and probably in many other parts of the tropics. Very often epidemics occur among the crews of men-of-war stationed in the tropics, as observed by Clayton.

Ætiology.—Manson found a diplococcus; other observers have described Leishmania-like bodies; in Clayton's and our experience the examination of the contents of the vesicles shows the presence of cocci generally arranged in pairs, and having often a gonococcus-like shape. They are, however, Gram-positive, and in cultures present all the characters of the *Staphylococcus pyogenes aureus* and *albus*. The disease is probably spread by contact.

Symptomatology.—The affection has nothing to do with that group of diseases to which writers on dermatology apply the term 'pemphigus,' for it is much more closely related to impetigo. The eruption attacks generally the axilla, the inguinal and crural regions, from whence it often extends to the abdomen and back and limbs; rarely affecting the face. It is extremely contagious, and is generally more severe in individuals who perspire profusely and suffer from prickly heat. The eruption is made up of flattened, roundish vesicles, which quickly enlarge to the size of a small pea. Very large, flabby, pemphigoid bullæ may occur, but not very frequently. The contents are at first transparent, but soon become turbid. The vesicles are often surrounded by a pinkish or reddish inflammatory halo. On being pricked, the vesicle collapses. The eruption does not usually affect the general health, but may be very persistent. As soon as the patient goes to the hills or to a cool climate it disappears spontaneously.

Diagnosis.—This is generally easy, the only difficulty being with chicken-pox. The absence of fever and the situation of the vesicles, which in *Pemphigus contagiosus* usually appear in the crural axillary regions, however, should be sufficient to exclude this. The absence of crusty lesions differentiates the disease from impetigo contagiosa.

Treatment.—The affected regions should be disinfected regularly twice daily with a solution of perchloride of mercury (1 in 1,000), carbolic acid (2 per cent.), permanganate of potash (1 in 4,000), hydrogen peroxide (10 per cent.), cyllin (1 in 300), or, in our experience best of all, lysoform (3 to 5 per cent.). After this the vesicles are pricked, and the parts again washed with the disinfectant, an antiseptic powder being then thickly applied, such as:

Acidi borici	ʒi.
Talci ven.	℥i.
Europhen	ʒi.
Talci ven.	℥i.
Dermatol	ʒi.
Talci ven.	℥i.

In some patients an ointment (europhen, 2 per cent.; protargol, 5 per cent.) answers better; the protargol ointment should never be used for the face, as it discolours the skin after a time. After the eruption has disappeared, it is advisable to use some Condy's Fluid or other disinfectant in the bath to prevent relapses; and, if the skin is not too tender, a formalin soap may be regularly used. The underclothing should be regularly dusted with one of the above powders.

PYOSIS TROPICA.

Synonym.—Kurunegala Ulcers.

Under the name 'pyosis tropica' Castellani has described a skin disease very common in Ceylon and Southern India. In Ceylon it is called by the natives Kurunegala sore, as it is especially common in that district.

Ætiology.—The disease is probably due to the usual pyogenic cocci, and is allied to the ordinary impetiginous and ecthymatous conditions, though much more severe.

Symptomatology.—The patient, generally a young boy or girl, though adults may also suffer, presents on the legs, arms, and occasionally all over the body except the face, numerous crusty lesions, occasionally rupia-like, of a dirty blackish or yellowish colour. If the thick crust is removed, a shallow ulcer with an irregular margin and granulating fundus will be seen, or a small flattened, or hemispheric nodule the size of a pea, with a pinkish, smooth surface. Besides these large lesions small papulo-vesicles and minute pustules are often present. The larger lesions are frequently surrounded by a halo of hyperpigmentation. There is severe pruritus. On healing, also, the ulcers and nodules leave a zone of hyperpigmentation or more rarely apigmentation. In chronic cases plaques of hypercheratosis may develop, especially on the exterior regions of the arms and the elbows.

Diagnosis.—On superficial examination, the disease might be easily mistaken for frambœsia. In contrast to frambœsia, the ulcers are superficial, and the nodules are generally small, have no moriform surface, and in scrapings from the lesions the *Treponema pertenue* is absent. From scabies it is distinguished by the absence of furrows and absence of the *Acarus*.

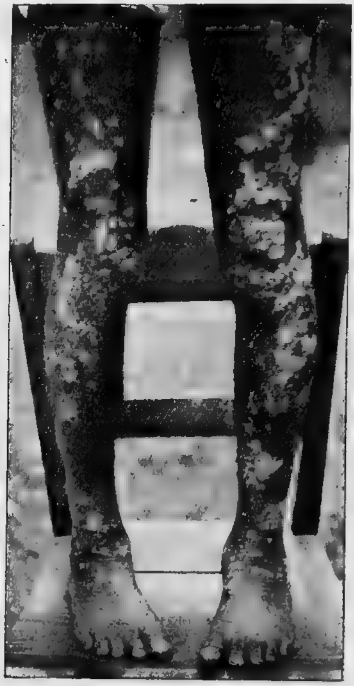

FIG. 349.—PYOSIS TROPICA.

The white patches are in reality thick yellow crusts.

Prognosis and Treatment.—If the disease is not properly treated, it has a tendency to become chronic. The treatment consists in removing the crusts by soaking them with a salicylic oil, made according to the following formula :

Acidi salicylici	gr. xxx.
Olei ricini	q.s.
Olei olivæ	ad ℥iv.

or by compresses soaked in hot boric lotion.

All the lesions are then disinfected with a solution of perchloride of mercury (1 in 1,000), carbolic acid (2 per cent.), cyllin (1 in 300), or permanganate of potash (1 in 4,000). A slightly antiseptic ointment is then applied, such as europhen (2 per cent.), iodoform (2 per cent.), protargol (5 per cent.). An ointment which in our experience is often efficacious is β-naphthol gr. v., acidi carbolici gr. x., vaselini ad ℥i. In some cases the opsonic treatment gives satisfactory results. The vaccine should be prepared with staphylococci grown from the lesions.

PURULENT FOLLICULITIS OF THE LEGS.

This affection is common in Ceylon and Southern India, in the former especially among the Moormen. The patient presents on his legs—especially the extensor region—numerous whitish conical pustules. Each pustule is pierced by a hair. The pustules remain, as a rule, separate, do not increase in size to any extent, and do not coalesce nor form crusty lesions. After a time the skin of the legs may show a peculiar parchment-like appearance. The examination of the pus contained in the pustules shows the presence of the ordinary staphylococci. The disease, if left untreated, runs a very long course. The treatment consists in depilation, application of antiseptic dressings, and, later, the application of an antiseptic ointment or paste. In obstinate cases the opsonic treatment, carried out with a vaccine prepared from the staphylococci grown from the lesions, gives good results.

PYOSIS PALMARIS.

This is a rare disease met with in native children. It is characterized by the presence of numerous discrete, conical, white pustules on the palms of the hands. The pustules do not coalesce together nor form crusts ; they are not surrounded by any marked inflammatory halo. Pruritus is slight or absent. The ordinary pyogenic cocci are found in the pus, but probably these are not the true cause of the eruption, inasmuch as neither the ordinary antiseptic treatment nor the opsonic treatment are of much use. The affection is differentiated from scabies by the pustular lesions not spreading outside the palms, by the absence of furrows and acari, and by the inefficacy of any anti-scabies treatment.

DERMATITIS RIMOSA OF THE TOES.

Synonym.—Mango toe.

In India, Ceylon, and many other tropical countries a peculiar dermatitis of the toes is common, which is the cause of great distress to European residents, especially during the hot season. The patient first complains of great itching between the toes, without their being present any papular or vesicular lesion. On scratching to relieve this itching, portions of the epidermis become removed, and small superficial, red, irritable abrasions are seen. These become deeper, and may become infected by the ordinary pyogenic cocci; deep, extremely painful fissures appear between the toes in almost all the cases. This dermatitis is difficult to cure, but disappears rapidly on the patient going to the hills or to Europe. The treatment consists in keeping the patient at rest for a few days, dressing the affected parts continuously with diluted carbolic lotion (½ per cent.), or resorcin lotion (½ to 1 per cent.), and later applying a zinc oxide paste, hazeline cream, or a bismuth-boric ointment (bismuth subnitratis, gr. xxx.; acidi borici, gr. xv.; vaseline, lanoline, āā ʒiv.). The stockings should be white, and should be changed at least twice daily, and should be boiled before use. A little boric powder may be sprinkled in them.

DERMATITIS BULLOSA PLANTARIS.

Cantlie has called attention to a peculiar dermatitis of the toes and soles of the feet, which has, apparently, some resemblance to dermatitis rimosa of the toes, though it is far more severe. He calls the affection 'foot-tetter.' It commences with blebs on the sole of the foot. The blebs ultimately break, and by-and-by bare scaly flakes of skin form, and extend all over the sole and between the toes. There is intense itching. Occasionally it spreads to other parts of the body. It usually dies away in the cold season, but recommences in the hot season. According to Cantlie, patients who have returned to Europe see their affection reappearing regularly every summer for ten or twenty years after leaving the tropics. The cause of the disease is unknown. Cantlie recommends as a palliative the application of pastes and plasters; Manson advises the use of a daily foot-bath of a 2 per cent. solution of carbolic acid for half an hour.

VELDT SORE.

Synonyms.—Natal Sore, Barkoo Rot, Ulcerative Dermatitis (A. Plehn).

This sore is very common in South Africa, and during the Boer War the British Army, especially the mounted troops, suffered from it greatly. We have seen cases in Tropical Africa, and the same affection, or a very similar one, has been described in Australia (Queensland), where it is known under the name of Barkoo, or barkoo rot.

Ætiology.—The disease is probably due to the ordinary pyogenic cocci. Harland grew the *Staphylococcus aureus* from his cases; in our cases we found a streptococcus. Harman, also, has found a streptococcus in his cases, which he calls *Streptococcus vesicans*.

Symptomatology.—This affection begins as very small superficial itching papules, which rapidly become papulo-vesicles or pustules and coalesce, forming a crusty lesion the size of a threepennypiece to a crown. If the crusty exudation be removed, the sore will appear in most cases as a superficial, very shallow ulcer, with a red fundus and roundish or somewhat festooned margins. The ulcer exudes a fluid pus which soon dries into a thin, crusty mass. The ulcer may be painful, but, especially at the beginning, there is frequently more itching than pain. The proximal lymphatic glands may be enlarged. Several such sores may be present at the same time. The hands, forearms, feet, and legs are mostly affected. Harman has seen as many as twenty such sores on one man. The duration of the affection varies between one and three months, but occasionally may last as long as six months.

Treatment.—The treatment consists in keeping the sores dressed with antiseptic lotions, or in washing the sores with a disinfecting lotion, and then applying an antiseptic powder, paste, or ointment, such as europhen (1 to 3 per cent.), iodoform (1 to 3 per cent.), protargol (5 to 10 per cent.) or calomel.

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CHAPTER LV

SKIN DISEASES (*continued*)—TROPICAL DERMATOMYCOSES

Tropical dermatomycoses—Tinea cruris—Tinea albigena—Tinea alba—Tinea sabouraudi—Tinea nigro-circinata—Tinea imbricata—Tinea intersecta—Tinea flava—Tinea nigra—Blastomycosis—Sporotrichosis—Aspergillosis—Pennicilliosis—Pinta—References.

TROPICAL dermatomycoses—that is to say, tropical skin diseases caused by fungi higher than bacteria—may be classified as follows:

TROPICAL DERMATOMYCOSES.

I. Due to fungi of the genus *Epidermophyton* Sabouraud 1907	*Ep. cruris* Castellani, Tinea cruris, dhobie itch	
	Ep. perneti Castellani, variety of Tinea cruris.	
	Ep. rubrum Castellani, variety of Tinea cruris.	
II. Due to fungi of the genus *Trichophyton* Malmsten 1845	*T. albiscicans* Nieuwenhuis, Tinea albigena.	
	T. macfadieni Castellani, Tinea alba.	
	T. blanchardi Castellani, Tinea sabouraudi.	
	T. ceylonense Castellani, Tinea nigro-circinata.	
III. Due to fungi of the genus *Endodermophyton* Castellani 1909	*En. concentricum* Blanchard, Tinea imbricata.	
	En. castellanii Perry, Tinea intersecta.	
IV. Due to fungi of the genus *Malassezia* Baillon 1889	*M. tropica* Castellani, Tinea flava.	
V. Due to fungi of the genus *Foxia* Castellani 1908	*F. mansoni* Castellani, Tinea nigra.	
VI. Due to fungi of the genus *Microsporoïdes* Neveu-Lemaire 1906	*M. minutissimus* Burchardt, erythrasma.	
VII. Due to fungi of the genera *Saccharomyces* Meyer 1838; *Cryptococcus* Kützing 1872	*S. gilchristi* and other as yet not well-determined species.	Varieties of tropical blastomycosis.
VIII. Due to fungi of the genus *Sporotrichum* Link 1809	*S. indicum* Castellani, Variety of tropical sporotrichosis.	

IX. Due to fungi of the genera *Aspergillus* Micheli 1727 ; *Penicillium* Link 1809	*A. barbæ* Castellani, Aspergillosis of hairy parts. *P. barbæ* Castellani, Penicilliosis of hairy parts.	
X. Due to fungi of the genera ..	*Aspergillus* Micheli 1725 *Penicillium* Link 1809 *Monilia* Persoon 1801 *Montoyella* Castellani 1907	Pinta.
XI. Due to fungi of the genus *Trichosporum* Behrend 1890	*T. giganteum* Behrend, piedra.	
	Species as yet not well determined.	Tropical varieties of nodular trichomycosis.

TINEA CRURIS.

Synonyms.—Dhobie Itch, Tinea Inguinalis, Eczema Marginatum.

Historical and Geographical.—Tinea cruris is extremely common all over the tropics ; it is met with also in subtropical regions, and in temperate zones, being first described by Hebra in Europe, where it is now well known owing to the researches of Sabouraud and Mibelli. In 1905 Castellani, as the result of the investigation of numerous cases, came to the conclusion that it should be separated from the ordinary forms of tinea corporis, the fungi causing dhobie itch being different species. Macleod suggested the name *Tinea cruris* for the affection. In 1907 Sabouraud created the genus *Epidermophyton*, the fungi found in *Tinea cruris*.

Ætiology.—According to Castellani's researches, at least three different species of epidermophytons may give rise to the eruption—*Ep. cruris, Ep. perneti, Ep. rubrum*—and there are probably several varieties of each species.

Epidermophyton cruris Castellani 1905 (synonyms, *Trichophyton cruris* Castellani 1905, *Epidermophyton inguinalis* Sabouraud 1907, *Trichophyton castellanii* Brooke 1908).—This is the commonest species ; in Ceylon the majority of the cases are due to it.

The fungus is very abundant in recent cases, but it is extremely scarce in cases of old standing. The mycelial tubes in fresh cases are generally straight, have often a double contour, and the segments are rectangular, their breadth being $3\frac{1}{2}\,\mu$ to $4\frac{1}{2}\,\mu$; branching is not rare ; the spores are rather large (4 to $7\,\mu$), roundish, and present a double contour ; they never collect in clusters. In chronic cases degeneration forms of the fungus are met with ; the mycelium may be banana-shaped, presenting several constrictions, or long strings of ovoid elements may be seen.

The fungus is easily grown by using sugar media, of which the best is Sabouraud's maltose agar. In cases of old standing the fungus is grown only with great difficulty, owing to the scarcity of it in the lesions ; the material to be inoculated must be taken from the edges of the lesion. The growth begins to be visible after five to nine days ; the rate of growing is very slow. After three to four weeks the colonies are often about $\frac{1}{2}$ inch, and even much more, in diameter. The colonies are often orbicular-shaped, hard, and with a pulverulent surface. The colour at first is greyish-yellowish, with occasionally a greenish tinge ; later it becomes greyish white.

Inoculation experiments on man with pure cultures, with the object of reproducing the disease, were tried by Sabouraud and Castellani, but without success.

Epidermophyton perneti Castellani 1907.—This *Epidermophyton*, which has been investigated by Pernet, is microscopically very similar to *Ep. cruris ;* the cultural characters, however, are different, the fungus growing much more rapidly, and presenting a pinkish colour, which is always lost in subcultures. This fungus is found in very rare cases only. Clinically the lesions caused by it are indistinguishable from those caused by *Ep. cruris.*

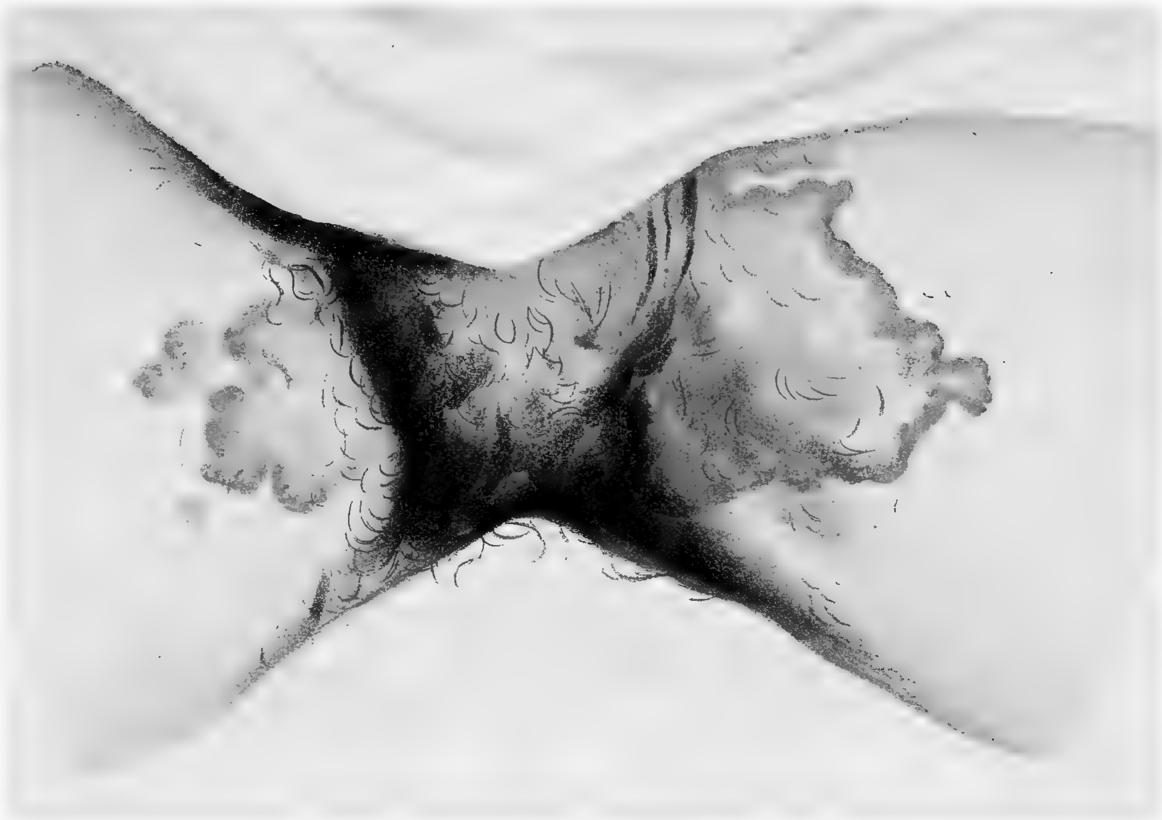
Epidermophyton rubrum Castellani 1909.—In fresh preparations the fungus resembles *Ep. cruris* and *Ep. perneti*, but the mycelial segments are often shorter.

In glucose-agar and Sabouraud's agar the growth shows a beautiful deep blood-red colour, which is not lost in subcultures. In ordinary agar cultures the pigment is always absent, the growth being of a whitish-grey or slightly greenish colour.

Symptomatology.—The term ' dhobie itch ' is used very loosely in the tropics by the lay public to denote practically any pruriginous skin affection. The term is, however, specially used to denote a form of severe pruriginous affection which mostly affects the inner surface of the thighs. occasionally the axillæ, and, in stout women, the regions under the breasts. It is in this stricter meaning that the term is used by medical men practising in the tropics.

The clinical features of the affection correspond to Hebra's ' eczema marginatum.' In a well-marked case the perineum, scrotum, and the inner surface of the thighs present large festooned patches, with an elevated abrupt margin ; the whole of the patches are bright red, or, in a later period, the margin only is red, while the rest of the patch is of a fawnish colour, or even of normal colour. The pruritus is unbearable. Owing to scratching, a secondary pyogenic infection or an eczematous-like dermatitis may develop. The disease, if not properly treated, is extremely chronic ; the condition improves during the cold season, but gets worse again during the hot months. Patients who suffer badly from dhobie itch may get almost well in a few days, without any treatment, on going to the hills ; on coming back to the plains the pruritus and all the other symptoms reappear. The affection has been known to last for many years. It is to be noted that after a time the eruption may spread to the other parts of the body—the abdomen, the trunk, legs, etc. In such situations it may develop in rings, or may form solid elevated dark red patches ; while the disease may be clinically indistinguishable from ordinary tinea circinata. It is to be noted, however, that the rings have generally a thicker edge, and the patches are coarser, of a deeper red colour, and larger than in ordinary tinea circinata. Mixed infections of tinea cruris and tinea circinata may occur, presenting the two

PLATE VII.



TINEA CRURIS.

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fungi growing on the same patient, though in different regions of the body. Several such cases have been described by one of us.

Clinical Varieties.—The above description mostly applies to the disease as produced by *Epidermophyton cruris* and *Ep. perneti.* In the cases due to *Ep. rubrum* the affected parts often present from the very beginning an eczematoid appearance, the patches being reddish, and covered with pityriac squamæ, and often, especially at the edge, with minute bloody crusts. The edge is not so elevated as in the other types of *Tinea cruris.* This type of *T. cruris* has great tendency to spread to other parts of the body.

Communicability.—Tinea cruris is known in the East as dhobie itch, from the popular belief that it is contracted from linen which has been contaminated while being washed by the dhobie (native laundryman). As to how far this belief is correct we are not in a position to say. We have never succeeded in finding the fungus in clothes newly received from the dhobie, either microscopically or by inoculating small portions of the linen in sugar media. We are, however, inclined to think that the popular belief may be to a certain extent correct. We have been told by old sufferers from dhobie itch, who used to be frequently reinfected, that on their ceasing to give their clothes to the dhobie, and having them washed in the house instead, the disease did not again affect them. In Colombo dhobies are in the habit of washing the clothes in a lake.

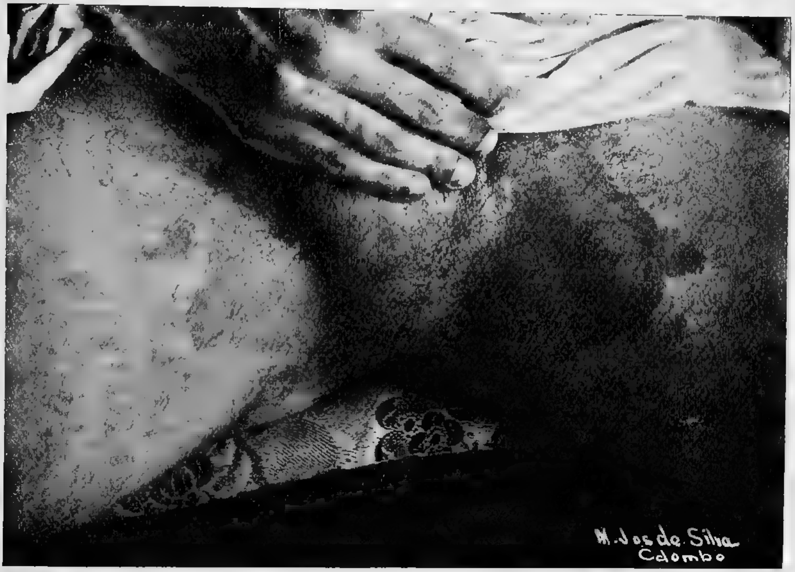

FIG. 350. — TINEA CRURIS IN A EUROPEAN.
From the same case as the coloured plate.

or in small pools of water more or less stagnant. It it certain that clothes belonging to infected persons are washed together with other clothes. Dhobie itch is very contagious; true epidemics occur in schools and among soldiers in barracks.

Diagnosis.—The diagnosis is easy in recent cases, the festooned appearance of the eruption, limited by a sharp, elevated, bright-red edge, being quite typical. In old cases, especially when secondary lesions due to scratching are present, the diagnosis may be very difficult, the affection being often mistaken for eczema.

In doubtful cases the microscopical examination will be of great help. It must, however, be noted that in old cases the fungus may be extremely scarce, the mycelium being practically absent, and only a few spores being found ; it is well to take the scrapings for microscopical examination from the edge of the eruption. The differential diagnosis must be made from erythrasma, intertrigo, and eczema.

In *erythrasma* the patches have a fawnish or dark reddish colour, and present often a fine pityriasic desquamation ; the eruption is not limited by a raised red edge ; the fungus *Microsporoïdes minutissimus* is quite different from the fungi found in dhobie itch.

Intertrigo is very common in the tropics, especially in corpulent persons. The lesions are very superficial, have not a festooned contour, and the margin is not sensibly elevated ; no *Epidermophyton* or *Trichophyton* like fungi are found. Saccharomycetic intertrigo is rare ; there is no elevated margin, and the fungus is found to be a Saccharomyces (*S. samboni*).

Primary eczema of the scrotum, and of the skin of the thighs in contact with it, is as frequent in the tropics as it is in temperate zones. The eczema is generally of the moist variety ; the moist surface, the absence of the festooned elevated margin, distinguish it from tinea cruris. As already stated, however, an eczematous-like dermatitis due to scratching often develops after a time on old dhobie itch lesions.

Prognosis.—If the affection is not energetically treated, it has a tendency to become very chronic and last for years. Occasionally the eruption spreads to the whole body, forming rings or solid patches ; at other times a distressing dermatitis develops on old dhobie-itch patches, due to scratching. Tinea cruris may disappear during the cold season or when the patient goes to the hills, only to reappear as soon as the hot season commences. During the period of quiescence the skin of the affected regions often shows a brownish discoloration, furfuraceous, somewhat similar to erythrasma.

Treatment.—In tropical practice the usual treatment is a chrysarobin or goa powder ointment. Almost all the so-called dhobie-itch ointments sold as patent medicines contain goa powder.

Our usual line of treatment is as follows :

Mild Cases.—A resorcin salicylic ointment applied twice daily : Resorcin, ʒi. ; Ac. salic., gr. x. ; vaseline, lanoline, āā ʒiv. In some cases we use Vleminckx' solution or lotio calcii sulphurati (slaked lime 4, sublimed sulphur 4, distilled water 35. Boil together, evaporate and filter to produce 20 of solution), pure or diluted.

Severe Cases.—We use a chrysarobin ointment (2 to 5 per cent.). The result is generally fairly successful. The patient should be informed that the medicine stains the linen, often irritates the skin, and that occasionally unpleasant evidences of absorption may take place. In obstinate cases we use local applications of turpentine-oil in the morning, and at night a resorcin salicylic ointment; if the parts are much inflamed, at night simply a boric ointment. This treatment gives good results. Turpentine is generally well borne, but patients often complain of a smarting and burning sensation a quarter or half an hour after the application. Exceptionally one meets with patients who cannot stand turpentine.

Cases complicated with Eczematous Dermatitis and Fissures.—In such cases one is apt to use a soothing treatment by pastes, lead lotions, etc., with the idea of first healing the eczematous lesions. In our experience, however, when the microscopical examination has shown the presence of the fungus, it is best, as a rule, to start an energetic antimycotic treatment at once. To the rhagades which so often develop in the inguinal regions we apply a solution of nitrate of silver (arg. nitr., gr. xv.; sp. æth., ℥i.). We touch with this solution the rhagades and the moist parts; this application is somewhat painful, but the pain soon disappears, and the fearful itching is relieved almost immediately; moreover, the nitrate of silver destroys the fungus. At night we apply a resorcin and salicylic ointment or paste all over the eruption;* as soon as the parts have become less moist, we begin the turpentine or the chrysarobin treatment. A precaution which must always be observed during and after the treatment to prevent reinfection, is to dust all the undergarments with antiseptic powder—for instance, Manson's powder (ac. bor., zinc. ox., amyli, āā. p. æq.); salicylic powder (ac. salicyl., gr. x.; talci venet., ℥i.); menthol powder (menthol, gr. v.; alcohol, q.s.; talci venet., ℥i.); dermatol powder (dermatol, gr. x.; ac. borici, ℥i.). It is advisable to wear small bathing-pants, which can be washed in the house.

TINEA ALBIGENA.

This trichophytosis was first described by Nieuwenhuis in Java. Nieuwenhuis' researches have been confirmed and enlarged by Jeanselme in Indo-China and in Siam; in the latter country the disease is known as *khi*. The disease is fairly common in the Malay Archipelago, and is occasionally met with in Ceylon.

Ætiology.—The affection is due to a *Trichophyton* first described by Nieuwenhuis—*T. albiscicans* (Nieuwenhuis) 1907.

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* If the eczematous dermatitis is exceedingly moist and severe, instead of the resorcin salicylic paste, a lotion of resorcin 1 per cent., or glycerin, borax, and rose-water equal parts, should be used.

The spores in fresh preparations from scrapings are almost always absent ; the mycelium tubes are straight, occasionally showing a double contour ; they are often dichotomous. Nieuwenhuis has grown the fungus, using Sabouraud's sugar media ; the growth is very slow ; the colonies are whitish, and show a powdery surface.

Symptomatology.—The eruption generally affects the palms of the hands and the soles of the feet, but may extend to the forearms and legs, and may affect the nails. It begins with the appearance of small pruriginous spots on the palms and soles ; the epidermis becomes raised, and bullæ develop, containing at first clear serum ; the bullæ break, and the skin remains dry and peels off ; the parts remain tender, and there is desquamation and pruritus. A process of diffuse keratosis develops, the palms and soles becoming double their usual thickness ; deep fissures may be formed at the natural folds. Several horny semi-detached discs can often be seen at the dilated orifices of the sweat glands. The affection is very chronic ; it may begin in youth or in adult life. After some time a process of apigmentation of the skin sets in, white patches, leucoderma-like, developing, and extending often to the legs and arms.

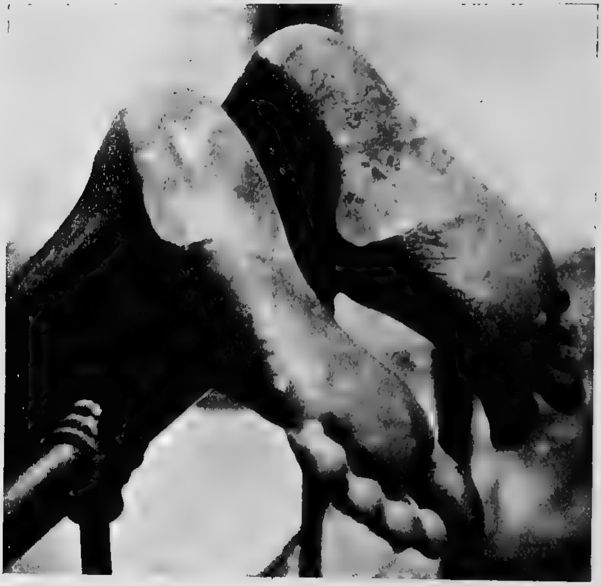

FIG. 351.—TINEA ALBIGENA.

Treatment.—Tincture of iodine and chrysarobin ointment (1 to 5 per cent.) answer fairly well, but the apigmented patches are not cured.

TINEA ALBA.

This tichrophytosis and its fungus were first described by Castellani in 1905. The disease is common in Ceylon, Southern India, and probably other parts of the tropics.

Ætiology.—The eruption is due to a *Trichophyton*—*T. macfadyeni* (Castellani) 1905—which is very abundant in the lesions. Mycelium and spores are of very small dimensions; the mycelial tubes are regularly shaped, do not show swellings, and are about 2½ μ in breadth. The spores are numerous, but not grouped in clusters, and present a peculiar oval shape, the maximum diameter being 2½ μ to 3½ μ. The fungus is very difficult to grow; on the rare occasions when the inoculations are successful the growth is very slow; the colonies coalesce, forming a browny mass with deep furrows, and deeply rooted in the media.

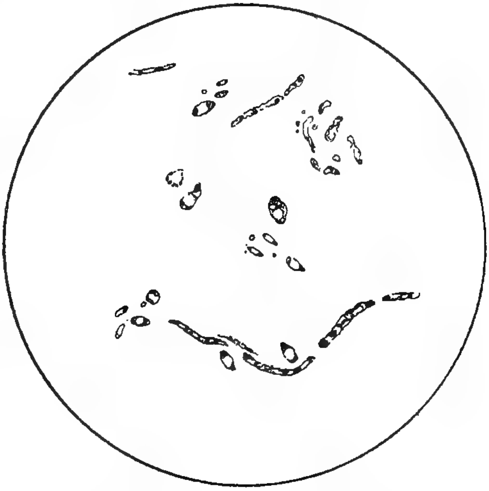

FIG. 352.—FUNGUS OF TINEA ALBA.

Symptomatology.—It may affect any region of the body, but is specially frequently noted on the arms and legs; it may occur on the face. White oval, roundish, or irregularly shaped patches are seen; the margins are slightly elevated, and may be dotted with minute papules. The surface of the larger patches presents a fine pityriasic desquamation. The course of the eruption is very chronic.

Treatment.—It is easily cured by the usual antiparasitic ointments, the best being chrysarobin ointment (2 to 5 per cent.).

TINEA SABOURAUDI.

This trichophytosis was first described by Sabouraud in patients returning from Indo-China, Japan, or Tonkin. We have seen a few cases in Ceylon.

Ætiology.—The disease is caused by the fungus *Trichophyton blanchardi* (Castellani) 1905—synonym, *T. sabouraudi* (Castellani) 1905*

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* The term *T. sabouraudi* cannot be applied to this *Trichophyton*, as this name has already been used for another *Trichophyton*—*T. sabouraudi* (R. Blanchard) 1905.

—which cannot be grown on Sabouraud's media or any other media we have tried. Microscopically the mycelial tubes do not show a double contour, and are not very straight; they are often banana-shaped. The segments of the mycelium are all separated; the mycelial spores are roundish, and are shed without forming a filament by their union. They are of various sizes.

Symptomatology.—The eruption generally commences on the uncovered parts of the body, generally on the legs; the patients often state that they think the disease is due to prolonged immersion in stagnant water. The affection begins with erythematous patches, the surfaces of which are covered with minute pityriasic squamæ. After reaching the diameter of about 1 or 1½ inches, the patches become circinate. The circination, however, is incomplete; it is only segmentary. In dependent positions large polycyclic patches may be seen, but only one-half or one-third of the circles are clearly seen, the rest being badly defined. The base of the patches, at this stage, is of a very dark bistre-brown colour. The border shows polymorphic lesions, fine pityriasic squamæ, minute vesicles and papules. The pruritus is very marked, and excoriations, due to scratching, are constantly present. In chronic cases a thickening of the skin, with lichenification, takes place, specially at the circinate borders.

Treatment.—The disease is difficult of cure in the tropics, though it may disappear spontaneously on the patient proceeding to Europe. Chrysarobin ointment (1 to 4 per cent.) is the best treatment.

TINEA NIGRO-CIRCINATA.

This trichophytosis has been observed by Castellan iamong Sinhalese natives.

Ætiology.—The eruption is due to a *Trichophyton*—*T. ceylonese* Castellani 1908. The spores are very few in number, roundish, rather large (4 μ), and showing a double contour. The mycelial tubes are about 3½ μ in breadth, generally straight. The fungus does not grow on any of the ordinary or Sabouraud's media.

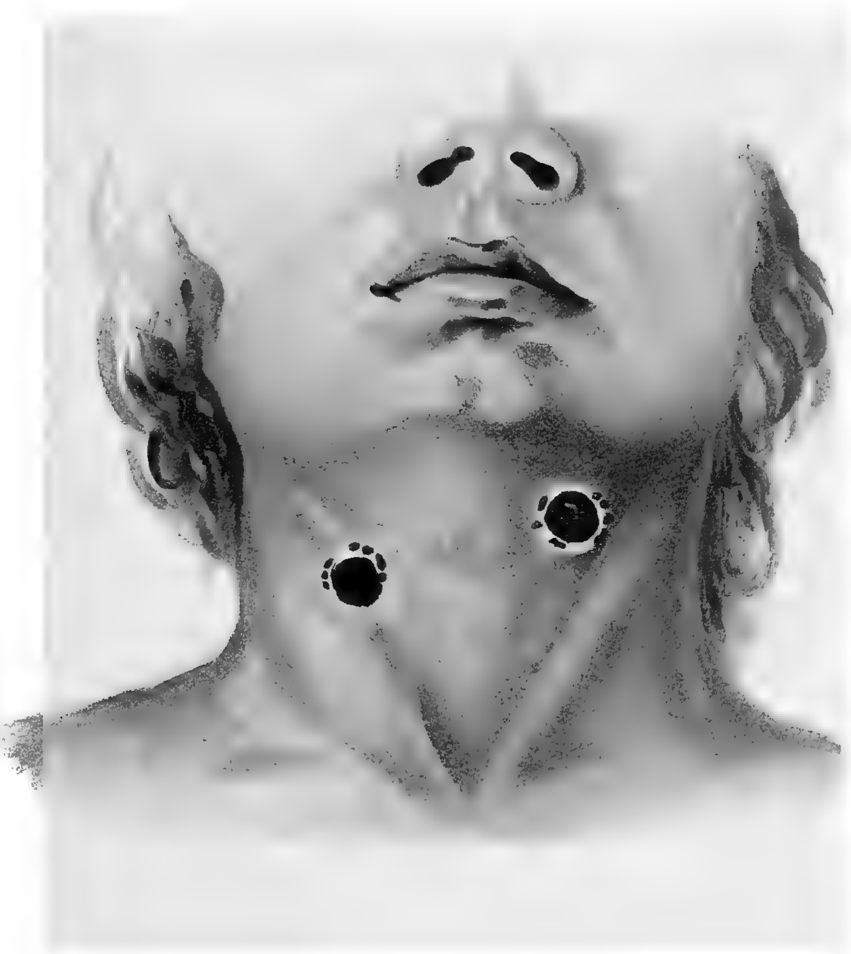
Symptomatology.—The eruption is found most frequently on the neck and scrotum, and consists of a few rings with thick, elevated margins, the encircled skin being black—much darker than the healthy skin—but not thickened nor presenting papules, vesicles, or pustules. The edge is thick, much elevated, of a dark colour, with the upper portion pinkish or occasionally covered by a dark crust. The eruption often heals spontaneously, leaving dark roundish patches at the previous seat of the lesions.

Prognosis.—The eruption may disappear spontaneously, and the treatment is easy.

Diagnosis.—The only dermatomycosis to which it has a slight resemblance is *Tinea sabouraudi*. The latter, however, is very chronic, and invades large portions of the body; the rings are segmentary, not complete, and the edge is not so thick and elevated.

Treatment.—Tincture of iodine, freely applied, answers well.

PLATE VIII.



TINEA NIGRO-CIRCINATA.

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TINEA IMBRICATA.

Synonyms.—Tokelau (Samoa); Gogo (Marshall Islands); Pita (Bowditch Islands); Cascado (Moluc Island); Dermatomycosis Chronica Figurata Exfoliativa (Thomson); Herpes Farinosus (Ritter); Herpes Desquamans (Turner); Herpes de Manson (Roux).

Historical—Geographical Distribution.—The first reference to this disease is found in Albert's atlas, 1832. Fox, in 1844, described it under the name of 'gune.' He observed it in the Gilbert Islands, and 'gune' was the term used by the natives to indicate it (gune = skin). It is to Manson that we owe the first scientific description of the disease and the discovery of its fungus; he introduced the term 'tinea imbricata,' under which the disease is now generally known. Manson's researches have remained classical. Further researches were made by Turner, Königer, MacGregor, and more recently by Tribondeau, Nieuwenhuis, and many others. The disease is extremely common in Fiji and many other of the Pacific Islands; it is found in the Philippine Islands, in Southern China, Tonkin, Malay Peninsula, and Java. Lately the distribution of the disease has much extended; several cases have been seen by us in Ceylon and Southern India, in which countries the disease was believed to be non-existent. Cases have also been reported from Brazil and other parts of tropical America.

Ætiology.—The affection is caused by an *Endodermophyton* first discovered and described by Manson—*En. concentricum* (Blanchard) 1901; synonym, *T. mansoni* (Castellani) 1905.

Description of the Fungus.—In all the cases observed by us the characters of the fungus corresponded with those given by Manson, rather than with the descriptions of later observers, as Tribondeau. The fungus is very abundant, growing between the rete Malpighii and the more superficial strata of the epidermis. Fresh preparations of scales in liq. potass. show a diffuse mass of interlacing mycelium. The segments of the mycelium vary greatly in length; their breadth is between 3 and 4 μ. They are generally straight and of regular outline, not showing swellings or constrictions; the spores are rather large (4 to 5 μ), oval, or somewhat rectangular. Aspergillar-like fructifications have not been observed by us, and we have seldom succeeded in growing the fungus.* Strong says, also, that he has been unable to grow the fungus in the Philippine Islands. According to Nieuwenhuis, however, the fungus may easily be grown on various media. He states that the growth is slow, and that the colonies are thick, crateriform, of a dark brownish colour. By inoculating such cultures in a European, he reports that he has reproduced the disease.

Tribondeau describes aspergillar-like fructifications in the fungus, which he calls *Lepidophyton* (λέπις = scale; φυτόν = plant). He has not succeeded in growing it. Wehmer has confirmed Tribondeau's results. In our experience, the fungus never shows aspergillar fructifications. In old scales kept in the laboratory for several weeks we have seen aspergillar-like fungi, but we believe them to be contaminations, as they are frequently found, for instance, in old blood-films, in old psoriasis scales, etc. It is not rare in the tropics to find aspergillar-like fungi even on the skin of normal persons, especially when they do not bathe frequently.

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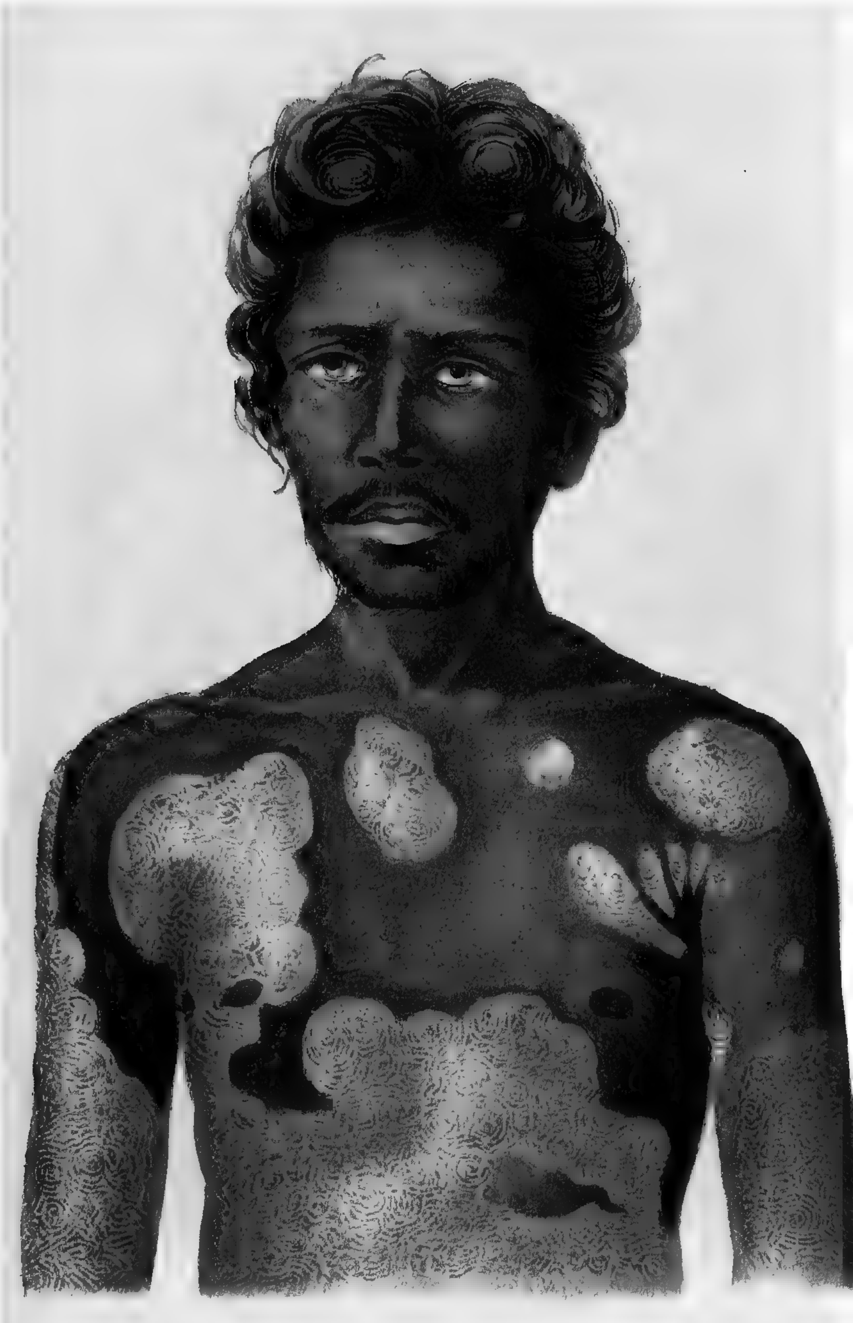
* In the two cases in which, by special procedure, some growth appeared, it grew slowly, was scanty, and showed a whitish greyish appearance, and was mostly submerged.

Symptomatology.—In a well-marked case the skin of practically the whole body is covered with round patches, each of which presents several concentric scaly rings. The scales are flaky, resembling tissue-paper, dry, of a dirty greyish colour, and slightly curled. If the scales are removed, rings of concentric circular dark lines remain visible. The number of rings forming the patch varies. Tribondeau states that they are not more than four ; we have, however, frequently counted as many as eight and ten in the same patch. The eruption may spread to any part of the body, except, in our experience, the scalp. Though several authors state that the eruption never affects the face and axilla, and rarely the palms and soles, we have often observed it in such situations. It is also stated that the nails are not affected, though Manson, who first completely described the disease, said that the nails being affected was of frequent occurrence. Our experience tallies with that of Manson. The nails, when affected, are much thickened, have a rough surface and deep cracks. Scrapings examined in liquor potassæ show the fungus. The fungus never invades the hair-follicles. The general health is not affected, but the patients complain of the disfigurement and of the unbearable pruritus. The pruritus increases much, apparently, if the patient is given certain diets—for instance, dry-fish diet. In the hot season the pruritus is much more marked. The disease is very chronic, and very difficult to cure.

As regards the development of the disease, we can confirm Manson's description, one of us having made several experimental inoculations. The period of incubation varies between seven and ten days. After this time a slightly elevated brown patch is seen at the place of inoculation ; the epidermis in the centre of the patch gives way, and a ring of scaling epidermis is formed ; this ring expands towards the periphery. The scales are free towards the centre, attached to the sound epidermis at the periphery. While the ring expands towards the periphery, in the centre again a dark patch appears, which later breaks, and another ring is formed inside the first, and so on.

In all our cases the blood showed a certain degree of eosinophilia, the number of eosinophile leucocytes varying between 6 and 16 per cent. In some cases this eosinophilia was probably due to the presence of intestinal worms ; the eosinophilia, however, was observed in some cases in which the microscopical examination of the fæces did not show any ova of worms. In very old cases the eosinophilia is more marked than in recent ones ; in old cases signs of anæmia may be present.

PLATE IX.



TINEA IMBRICATA.

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Prognosis.—The general health is not affected. The patient complains of the disfigurement, which is very great, and of the pruritus, which in the hot season may be unbearable. The disease has no tendency to recover spontaneously; its treatment is difficult, and cases apparently cured often show a return of the eruption after a few months.

Diagnosis.—The disease, once seen, cannot be confused with any other dermatomycosis; its development in concentric rings, fringed with tissue-paper-like scales, is absolutely characteristic.

Treatment.—Every medical man practising in the tropics well knows how difficult is the treatment of tinea imbricata. It is easy to obtain a temporary improvement, and even a disappearance of the eruption; but as soon as the treatment is discontinued, the eruption, as a rule, starts afresh.

Strong iodine liniment, as recommended by Manson, or resorcin dissolved in tincture of benzoin (resorcin, ʒii.; tr. benz., ℥i.), as recommended by Castellani, give, on the whole, the best results.

In the Colombo Clinic of Tropical Medicine the latter has made various experiments to test the efficacy of the various medicaments by applying simultaneously different liniments, ointments, etc., to symmetrical parts of the body, and comparing the result. According to his results:—

Sulphur has practically no effect whatever on the fungus.

Turpentine generally induces a slight improvement, some scales disappearing, and the skin becoming smoother; the improvement, however, is not permanent, and as soon as the turpentine application is discontinued the typical scales reappear.

Calomel and other ointments of mercurial preparations do not induce any improvement in the eruption.

Thymol and *Naphthol* ointments may cause a slight improvement.

Carbolic Acid and *Epicarin* ointments have no effect whatever.

Cyllin ointment (20 to 50 per cent.) may induce a temporary improvement.

Formalin is very effective for localized patches. The usual 40 per cent. solution is applied with care, treating each time a small portion of the eruption. Formalin often causes severe pain and a certain degree of inflammation, which is best relieved by applications of iced water. Soon after the application of formalin the patches become dark brownish, which colour lasts for a few days, when they clear. Care must be taken not to apply the formalin to too large portions of the skin, and not to repeat the application too often; otherwise a peculiar form of apigmentation, similar to leucodermic patches, may appear later on, to which disfigurement coloured patients strongly object.

Chrysarobin.—The repeated application of chrysarobin ointment (30 grains to 1 ounce of vaseline) may induce a strikingly rapid improvement in cases which are not of long standing. The eruption, however, recommences a few days or weeks after its apparent disappearance. Chrysarobin is a very toxic medicament; the patient must be watched and the urine regularly examined. In one of our cases symptoms of absorption appeared after a single application.

Salicylic Acid and *Methyl Salicylate* have very little, if any, action on the fungus.

Tinctura Iodi and *Linimentum Iodi.*—Tinctura iodi, freely applied, induces a very marked improvement, which, however, is not permanent. Strong iodine liniment, as recommended by Manson, is most effective; it cannot be used freely, however, on patients with a delicate skin, such as women and children.

Resorcin and Tincture of Benzoin.—Resorcin, alone or mixed with salicylic acid in alcoholic solution and in ointments, has very little efficacy. If, however, resorcin be dissolved in tinctura benzoini composita (60 to 120 grains of resorcin to 1 ounce of the tincture of benzoin), very good results are obtained; it is now the routine treatment for tinea imbricata in the Colombo Clinic. It is to be noted that tincture of benzoin without resorcin has very little action on the eruption. The resorcin, dissolved in tincture of benzoin, should be applied freely once or twice daily on the affected regions. If the whole body be affected, one day one half is painted, and the other day the other half, alternately. The treatment must be continued for several weeks. Once or twice a week the patient is given a very hot bath, and scrubbed all over with sand-soap. Symptoms of absorption are rare; it is always prudent, however, to proceed at first with care, as it is well known that individuals may be met with, though rarely, showing idiosyncrasy for resorcin.

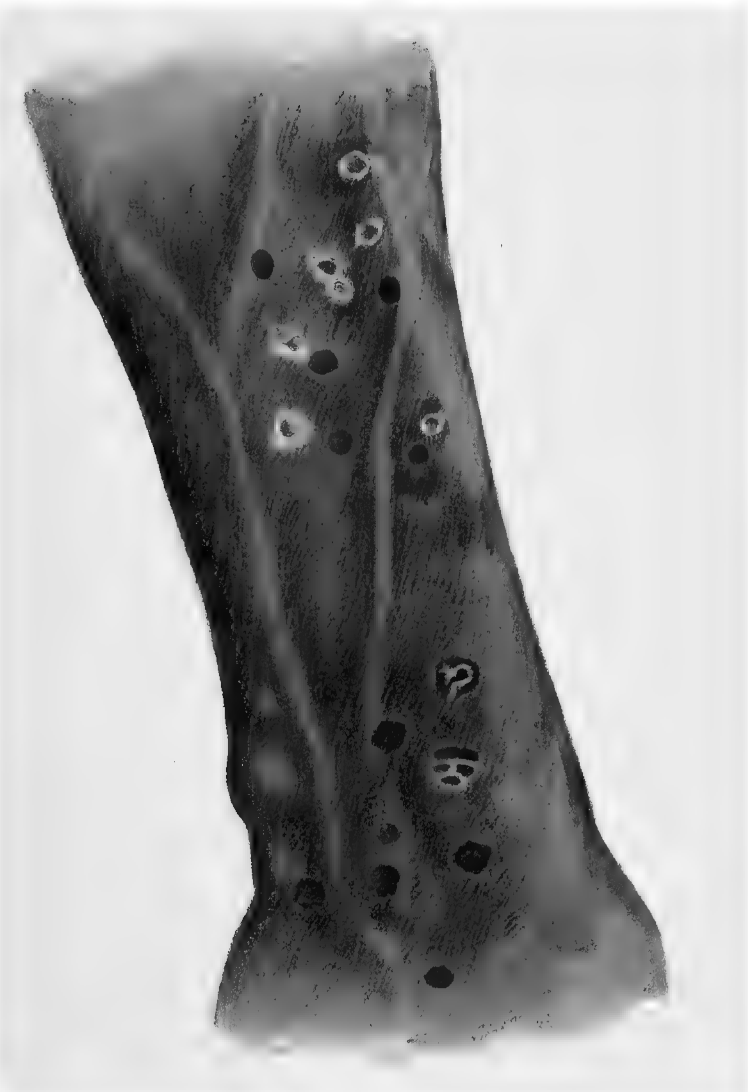
TINEA INTERSECTA.

This dermatomycosis and its fungus were first described by Castellani in 1907. It occurs in Ceylon and Southern India.

Ætiology.—If a portion of one of the brown patches or a scale be removed and treated with liquor potassæ, the fungus is easily detected. The fungus (*Endodermophyton castellanii* Perry 1907) grows between the superficial and the deep strata of the epidermis. It is present on the inner surface of the scales, but not on the external surface. A very remarkable fact is the extreme rarity of free spores; in fact, in several cases one does not succeed in finding spores. The mycelium is fairly abundant, though far from being so abundant as in tinea imbricata. It is composed of long, straight, articulated threads, which are sometimes dichotomous, the breadth being between 3 and $3\frac{1}{2}\ \mu$. No aspergillar fructifications nor clusters of spores are seen. So far attempts at growing the fungus have failed.

Symptomatology.—The eruption begins with small oval or roundish, very slightly elevated itching patches, generally situated on the arms, legs, chest, and back. The margins of these dark spots are at first slightly elevated, and dotted often with minute dark papules. The patches are dark brown in colour, much darker than the surrounding skin, and present a smooth, tense surface at

PLATE X.



TINEA INTERSECTA (FOREARM).

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first; they increase in size slowly, and some coalesce. After a certain time the surface of the patches is no longer tense; it becomes somewhat shrivelled and dry; superficial cracks appear in it, so that white lines are visible intersecting the brown surface. Later the cracks become deeper, the epidermis splits, and several flaky, curled-up scales, whitish inside and dark on the outer surface, are seen; the scales are often removed by friction, and whitish roundish patches only remain. The eruption never develops in concentric rings like tinea imbricata; the patches remain isolated or fuse together, forming irregular larger patches. Some patches may disappear spontaneously after a time. The general health of the patient does not seem to be affected. In some patients there is a slight degree of eosinophilia.

Diagnosis.—When the eruption is in the very first stage it might be mistaken for a form of pityriasis versicolor. In pityriasis versicolor, however, the epidermis does not split; moreover, in tinea intersecta the fungus is not found on the surface: it grows between the superficial and deep layers of the epidermis. Tinea imbricata begins in a manner somewhat similar to tinea intersecta, dark brownish patches being present, and the fungus in both eruptions growing between the superficial and deep layers of the epidermis. In contrast to tinea imbricata, however, the eruption of tinea intersecta never develops in concentric rings; is far less severe, as patches may heal spontaneously; and is cured without much difficulty.

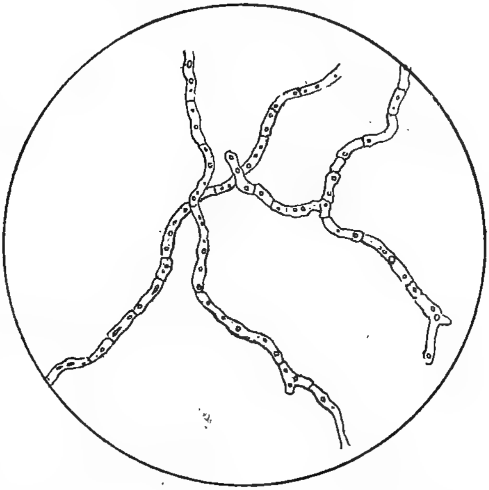


FIG. 353.—FUNGUS OF TINEA INTERSECTA.

Treatment.—Tincture of iodine and the usual antiseptic ointments, such as chrysarobin (2 to 5 per cent.), answer well.

TINEA FLAVA (*vide* Plate XI.).

Synonyms.—Tropical Pityriasis Versicolor of the old authors, Microsporosis Flava (Castellani), Achromie Parasitaire (Jeanselme), Pityriasis Versicolor Flava (Castellani), Achromia Squamosa (Crocker).

This dermatomycosis is extremely common in all tropical countries, and especially so in Southern India, Ceylon, Malaya, Java, Indo-China, and China. By many authors it has been, and is still, confused with the ordinary pityriasis versicolor of temperate zones; the investigations of Jeanselme and Castellani, however, have clearly proved that it is a different affection.

Ætiology.—The affection is due to *Malassezia tropica* Castellani 1905. The mycelial threads are generally thick, with numerous swellings, constrictions, and other irregularities in their shape. The spores are roundish or oval (3·50 to 4·50 μ), and have a double contour. In recent cases the fungus is abundant, with plenty of mycelium and spores which often run into clusters. In old chronic patches the fungus becomes very scanty; the spores are not numerous, and generally do not collect in clusters; the mycelium is very scanty, and is even more irregular in shape than it is in recent patches (degeneration forms of the fungus).

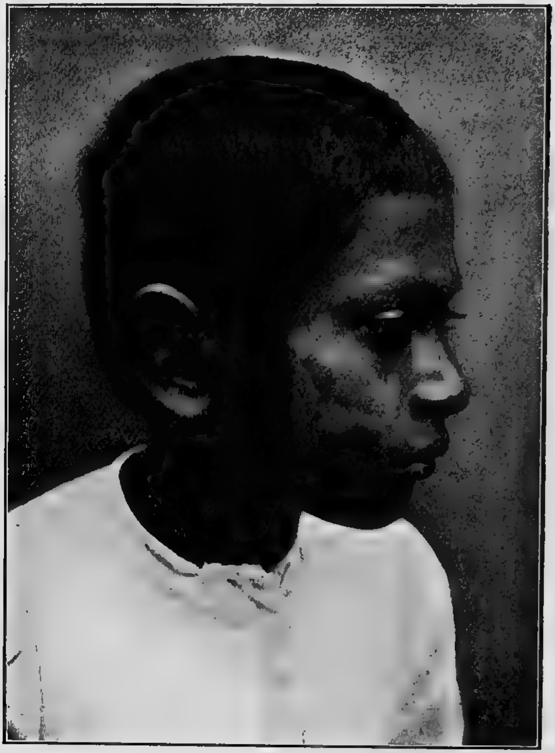


FIG. 354.—TINEA FLAVA.
On the face of a Sinhalese.

Symptomatology.—The affected parts are yellowish, of much lighter colour than the surrounding healthy skin; the yellow colour may be of various tinges, from dark, deep orange-yellow in some cases to very light canary-yellow in others. The patches are of various sizes, generally roundish, smooth, sharply defined, with margins not elevated, or only slightly so. Sometimes the patches are irregularly festooned, and may encircle an area of healthy skin. Occasionally the encircled healthy skin appears to be intersected by many yellowish, ribbon-like lines originating from the surrounding yellow patch. The regions more frequently affected are, in order of frequency, the face, neck, chest, and abdomen. Large portions of the body may be involved. There is no pruritus. The patches are not desquamating, or only very slightly so. The course of pityriasis flava is very chronic. In the natives of the lower classes it appears in childhood as tiny spots on the face and chest, spreading slowly during years; they may coalesce, covering practically the whole of the face and chest. One is occasionally surprised to see a native whose face and chest are quite light in colour; on closer examination, it may be found that this lighter appearance is due to a diffuse, very light-coloured form of tinea flava, covering the whole of the face, neck, and chest. In Ceylon native women, when the patches of Tinea flava are small, light, and situated on the face, they are considered as beauty-spots, and are highly appreciated by the ladies and their admirers. Such patches are called in Sinhalese 'alu-hama,' which means ashy skin (*alu*, ash; *hama*, skin). There is also another word used by native poets for such conditions—'gomera,' which means skin dotted with beauty-spots. The disease, which is extremely common, attacks mostly natives, but occasionally Europeans also. In Europeans the patches are yellowish-reddish or pinkish (tinea rosea), and may be due to different strains of *M. tropica.*

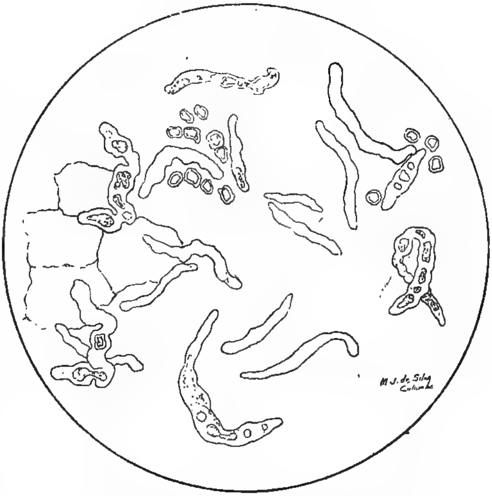


FIG. 355.—FUNGUS OF TINEA FLAVA.
(From a specimen stained by the Morris-Walker method.)

Prognosis.—The disease is very chronic, has no tendency whatever to spontaneous cure, but the general health is not affected.

Diagnosis.—*Pityriasis versicolor* of temperate zones is not of so light a tinge as tinea flava, never attacks the face, and is curable with the greatest facility; while tinea flava affects the face more frequently than any other part of the body, and is curable only with difficulty.

Tinea Alba.—Occasionally there may be some difficulty in distinguishing tinea flava of a light variety from tinea alba. In contrast to tinea flava, the patches of tinea alba are not smooth, and the fungus (*Trichophyton macfadyeni*) shows spores of a peculiar characteristic oval shape.

Tinea Flava and *Pinta* are easily distinguished by the characters of their respective fungi, the fungus found in pinta never having the characters of a Malassezia.

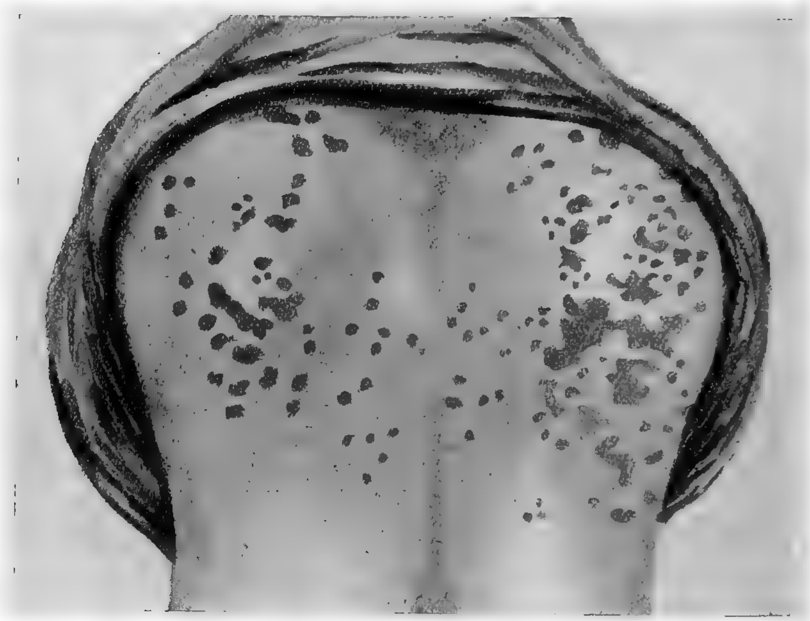


FIG. 356.—TINEA FLAVA ON THE BACK OF A EUROPEAN.

Leucoderma patches have a characteristic dead-white colour, are often surrounded by a hyperpigmented border, and no fungus is found.

In *Circumscribed Scleroderma* (Morphœa) the patches may present a peculiar yellowish tinge, which in coloured patients may resemble tinea flava. In tinea flava, however, there is no change in the texture of the skin, which is still pliable, and does not exhibit the peculiar parchment-like feeling of scleroderma. The microscopical examination will clear the diagnosis in any doubtful case.

In Europeans the reddish-yellowish variety of tinea flava might, on superficial examination, be mistaken for a form of *Seborrhœa* *corporis.* The microscopical examination will clear the diagnosis, no fungus being found in seborrhœa corporis.

Treatment.—Tinea flava shows no tendency to spontaneous cure, unless the patient moves to a cold climate. The treatment is difficult. Turpentine applied daily, followed by a naphthol or epicarin ointment (2 to 5 per cent.), or a salicylic-resorcin ointment (resorcin ʒi., acidi salicylici gr. x., vaselini ℥i.), is often successful, but the treatment must be continued for months. It is to be noted that in several cases the fungus of tinea flava has apparently a deep permanent disturbing action on the pigmentation processes of the skin, as, even when the fungus has been destroyed, the patches may remain of a lighter colour than the surrounding skin for a long time, though ultimately they become again normally pigmented.

TINEA NIGRA.

Synonyms.—Pityriasis Nigra (Castellani), Microsporosis Nigra (Castellani).

This affection is fairly common in India, Ceylon, Java, Federated Malay States, and China. The first account of this, or a very similar, dermatomycosis was published by Manson in China in 1872. Manson's observations, however, were forgotten, as they were not quoted by him in his subsequent works. Castellani, in 1905, redescribed the disease in Ceylon, and succeeded in growing the fungus which he called *Foxia mansoni*.

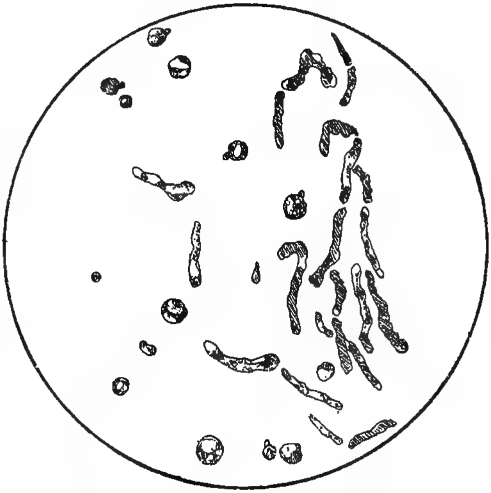


FIG. 357.—FUNGUS OF TINEA NIGRA.

Ætiology.—The affection is caused by a fungus of the genus *Foxia* — *F. mansoni* Castellani 1905. The fungus is found very abundantly in the lesions; the mycelial articles are rather short—18 to 20 μ in length, and $2\frac{1}{2}$ to $3\frac{1}{2}$ μ in breadth. Sometimes they may be irregular in outline, bent, banana-shaped. The spores are globular, and most of them very large—5 to 8 μ. They are frequently arranged in clusters.

The fungus is easily cultivated by inoculating scrapings of the affected patches on maltose agar. After two to four days roundish hemispheric colonies appear, which are black, but at first have usually a greenish tinge, and may present at the periphery some radiating, delicate, pale greenish hyphæ.

These colonies may remain separate or more often gradually coalesce into a jet-black knobby mass, deeply rooted into the medium.

The fungus grows well, though less abundantly, on the other sugar agars, and also on ordinary agar. In *broth* and *peptone-water* the growth is very slow, and takes place at the bottom of the tubes, with formation of a black or greenish-black sediment.

The *optimum temperature* for the growth of the fungus is between 30° C. and 32° C. ; above 35° C. and under 25° C. the growth is much slower, and may be nil under 20° C.

Symptomatology.—The affected parts are of a black, dull, lustreless colour, much darker than the surrounding dark, healthy skin of the native. The patches may be small, roundish, and separated from one another, or may coalesce ; the patches are often slightly elevated, and may present a slight desquamation. Little, if any, pruritus is present. The face is not usually affected, though the eruption may be found on practically any other region of the body. The neck and upper portion of the chest are apparently the regions most frequently affected. Tinea nigra usually attacks natives only. We have, however, seen it also in one of our European patients, who went for a pleasure trip to Burma, where he remained about a month. On coming back to Ceylon, he noticed a small, roundish, very slightly elevated, non-desquamating, black patch on the palm of his left hand. There was no pruritus. The patch spread slowly for two months, reaching the size of a sixpenny-piece. It disappeared after a single application of formalin ; three months later it reappeared in the same place as a tiny black dot, which slowly spread. Another application of formalin caused it to again disappear. From the patch a fungus was grown identical with the one found in native cases.

Mixed Infections.—A mixed infection of tinea nigra and tinea flava is somewhat frequently met with. Several of our patients had on the neck a few round patches of tinea nigra, and on the face some smooth, yellow, roundish patches of tinea flava.

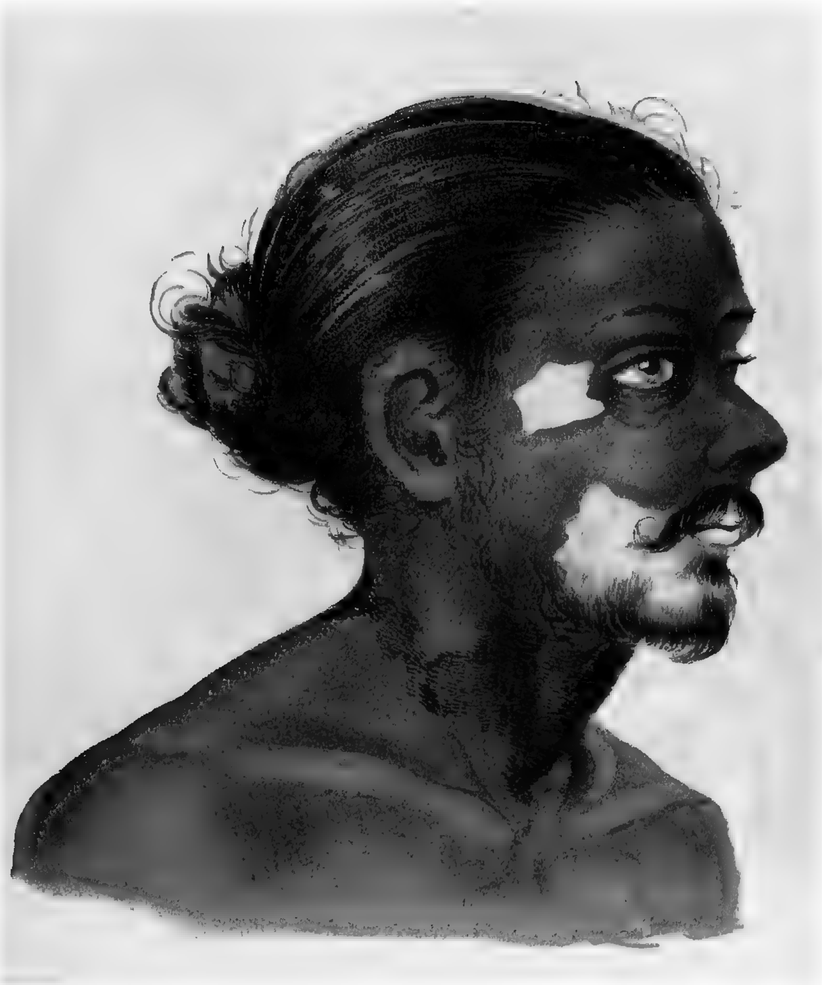
Prognosis.—The characters of the fungus, and the fact that the disease is very easily curable, readily distinguish tinea nigra from pinta. Pityriasis versicolor is generally of lighter colour than tinea nigra, and the fungus (*Malassezia versicolor*) is morphologically very different, and cannot be grown. In chloasma bronzinum no fungus is found.

Treatment.—The disease is easily curable, except when it attacks the palms of the hands, where the treatment must be more prolonged. A salicylic-alcoholic lotion (2 per cent.), followed by a resorcin ointment (resorcin, ʒi. ; vaseline, ℥i.), answers well. When the patches are small, pure formalin may be used with care.

ERYTHRASMA.

This affection is frequently met with in the tropics, and is common on the continent of Europe, though apparently rare in America.

PLATE XI.



TINEA FLAVA ON THE FACE AND
TINEA NIGRA ON THE NECK.

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Ætiology.—It is caused by a fungus discovered by Burckhardt in 1859—*Microsporoides minutissimus*. This hyphomycete is very delicate and slender, less than 1 μ in breadth ; is found in the superficial horny layer of the affected parts. Ducrey and Reale claim to have succeeded in cultivating it, but their results have not been confirmed.

Symptomatology.—The eruption generally affects the genito-crural and axillary regions, but may occasionally spread to other parts of the body. It is characterized by the presence of brownish-reddish patches, rounded or irregularly shaped, but with well-defined borders. The borders are not elevated ; the surface of the patches appears slightly furfuraceous, and has often a somewhat greasy feeling. There are no subjective symptoms, except occasionally slight itching.

Diagnosis.—Erythrasma is easily distinguished from tinea versicolor and tinea flava by the reddish tinge generally present ; by the characteristic difference of its sites of development, and by the microscopical examination which will reveal the presence of *Microsporoides minutissimus*, a fungus morphologically very different from *Malassezia versicolor* or *M. tropica*. The differential diagnosis from tinea cruris has been discussed in this chapter under the heading Tinea Cruris.

As first noticed by Manson, after tinea cruris has been cured, the genito-crural region may in some cases present for years a peculiar brownish discoloration, and be slightly furfuraceous—a condition resembling erythrasma ; in such cases neither *Epidermophyton cruris* nor *Microsporoides minutissimus* will be found.

Treatment.—Washing the parts with ordinary soap and warm water, carbolic, tar, or sand soap, and then regularly applying a resorcin-salicylic ointment, will soon cause the eruption to disappear. Instead of the ointment, a hyposulphite of soda or sulphurous acid lotion may be used.

BLASTOMYCOSIS.

Synonyms.—Saccharomycosis Hominis, Oidiomycosis, Dermatitis Blastomycotica, Blastomycetic Dermatitis.

Historical and Geographical.—Gilchrist, in 1894, first described yeast-like organisms in sections taken from a scrofuloderma-like eruption. In the same year, independently, Busse published a case of a pyemia-like condition due to a *Saccharomyces*. The disease has been investigated chiefly by American observers, among whom Ricketts, Ormsby, Hyde, Montgomery, and Pusey may be mentioned. The malady occurs in the tropics, and one of us has reported several cases from Ceylon, while Phalen and Nichols have described numerous cases from the Philippine Islands.

Ætiology.—The fungi found belong to the genera *Saccharomyces*, *Cryptococcus*, *Endomyces*, and higher, not yet well-determined fungi, all of which are apparently capable of inducing identical clinical conditions. In the tissues all the organisms exist as yeast-like oval or roundish cells. Among the organisms which cause the disease, four types (Ricketts) may be distinguished :

1. Blastomycetoid or yeast-like type : reproduction by budding; in cultures only oval or roundish cells are seen, while mycelial tubes are as a rule absent.

2 Cryptococcus-like type : reproduction by endosporulation within the tissues.

3. Endomyces-like type : the cultures present abundant submerged mycelium, which breaks up into chains of endoconidia ; proliferation by budding is rare.

4. Hyphomycetoid type : cultures present aerial hyphæ and submerged mycelium ; proliferation by gemmation occasionally seen. There are many transition forms between these four groups.

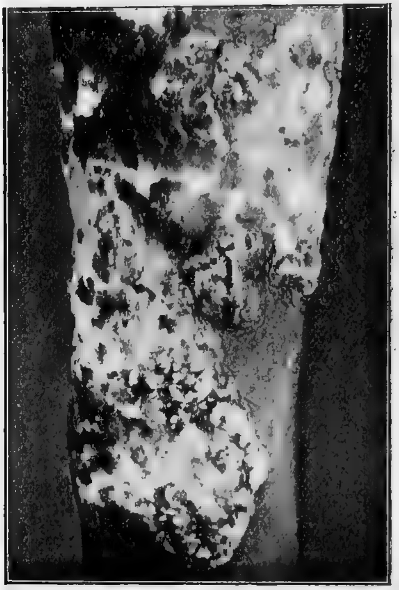

FIG. 358.—BLASTOMYCOSIS OF LEG.

Histopathology.—There is marked proliferation of the epithelial layers, with elongated, irregularly shaped downgrowths into the corium. The cells of the rete are swollen, and there is, between the cells, a polymorphonuclear leucocytic infiltration. Here and there minute miliary abscesses are present ; it is in the miliary abscesses that the organism is mostly found. The corium presents a general cellular infiltration made up of polymorphonuclear leucocytes and young connective-tissue cells. Occasionally a few giant cells may be seen. The vessels are dilated and their walls thickened.

Symptomatology.—The disease is characterized by the presence of elevated warty patches showing, especially at their margins, minute epidermal abscesses. The eruption may be gyrate. The lesions at a later stage may become ulcerated, the process of ulceration generally beginning at their centre. There is very little or no pain, and very slight or no pruritus. The lesions may heal spontaneously, leaving, as a rule, soft smooth scars. Occasionally the affection recommences after a time in the scar. The lymphatic glands are seldom involved. In some cases subcutaneous abscesses and gumma-like swelling may be formed ; all regions of the body may be affected. The course is very chronic.

Diagnosis.—The disease has been often confused with tuberculosis verrucosa, with a syphilide, with an epitheliomatous lesion, and, in the tropics, with atypical framboesia and even ringworm. The microscopical examination and cultivation of scrapings, or, better, of the pus of the miliary abscesses present in the lesions, will be necessary to clear the diagnosis. A droplet of the pus, or a minute portion of teased tissue, is placed on a slide with a drop of a 30 per cent. solution of potassium hydrate, and a cover-glass is placed on the preparation ; after about half an hour in a temperate climate, and generally a few minutes only in a tropical climate, the tissue and pus cells are disintegrated by the potash solution, while the organisms, being resistant, can be easily seen. Cultures should also be made from the pus. It is important to note that yeast-like organisms may be frequently found as saprophytes on the surface of various ulcerated skin lesions, which have nothing to do with true blastomycosis.

Prognosis.—The disease very rarely heals spontaneously. The general health is not much affected, but the patients complain of the disfigurement. Occasionally the organisms from the skin lesions enter the general circulation, and a condition similar to pyæmia develops. Cases of systemic blastomycosis terminating fatally, without any skin lesion, have also been described.

Treatment.—Potassium iodide, given in large doses, has a beneficial effect, though it is not so efficacious as in sporotrichosis. The application of Röntgen rays to the lesion is useful. In mild cases the local application of various disinfectants—*e.g.*, perchloride of mercury (1 in 1,000), dilute tincture of iodine, etc., may bring about a cure.

SPOROTRICHOSIS.

Schenk, in 1898, described a case of multiple chronic abscesses in the pus of which a *Sporotrichum* was found. Hektoen and Perkins reported two similar cases also in the United States in 1900. De Beurmann published in 1903 a case of similar nature in France. Beurmann and Gougerot, in 1906 and 1907, published several cases, and investigated the subject of human sporotrichosis bacteriologically and histologically, as well as clinically. Their researches have been confirmed by Gaucher and Monier-Vinard, Duval and Fago, Vaquez, Bonnet, Lanbry, and Esmeni. Cases have been reported recently from the tropics by Lutz and Splendore in Brazil, and by us in Ceylon. Clair has observed the disease in Arab stokers on board some steamers of the Messageries Maritimes Company.

Ætiology.—The fungi found belong to the genus *Sporotrichum*. *S. shenki* has been observed in the cases in North America ; *S. beurmanni* in the European and Brazilian cases ; *S. indicum* in the Ceylon cases. These fungi are morphologically very similar. In the human lesions the fungus appears morphologically as a yeast, and is very scarce. In cultures mycelial threads and numerous spores are seen. The spores are ovoid, 5 to 6 μ in length by 3 to 4 μ

in breadth. The mycelial filaments are very slender (2 μ) in *S. beurmanni* and *S. shenki;* somewhat broader (2½ to 3 μ) in *S. indicum.* These fungi grow easily on the ordinary culture media, best of all on Sabouraud's pepton-glucose-agar. Colonies develop from the fourth to the tenth day as small white points, surrounded by a delicately rayed aureola of whitish colour. They gradually increase in size, coalesce, become convoluted, and take a dark greyish, brownish, and even black colour. These fungi live apparently saprophytic on vegetables (lettuce-leaves, and other kinds of vegetables used as salads) and on insects (flies, caterpillars, larvæ). According to De Beurmann, infection takes place by contact with unclean vegetables.

The rat, mouse, monkey, cat, and very young guinea-pigs are all more or less susceptible, and may be infected by subcutaneous or intraperitoneal inoculation. The rat is the most susceptible animal. In this animal Lutz and Splendore have described a spontaneous sporotrichosis due to a *Sporotrichum* apparently identical with *S. beurmanni.* The affection has also been observed to occur spontaneously in the dog (Gougerot and Caravan) and in the mule (Fonteynot and Carongeon) in Madagascar.

Histopathology. — The histopathology of the cases due to *S. beurmanni* has been investigated by Beurmann and Gougerot. We have come to similar results in the cases due to *S. indicum.* The lesions present three principal types of reaction : (1) An epithelioid type, with presence of giant cells—this corresponds to the tuberculoid type of De Beurmann and Gougerot ; (2) a lympho-connective tissue or syphiloid reaction ; (3) a polymorphonuclear or a ecthymatiform type.

Symptomatology.—In a well-marked case, several gummatous-like swellings, situated in the subcutaneous tissue, are present on various parts of the body—the arms, legs, and trunk. The size varies from that of a small pea to that of an orange. On palpation, they are hard, resistant at first ; later they soften, the skin becomes reddish or violaceous, and after a time perforates. From the fistulous opening a yellowish homogeneous pus is slowly evacuated. In some cases the suppuration ceases, granulation sets in, and a coarse cheloid-like scar remains. In other cases the fistulous opening enlarges, and a crateriform ulcer, with often a fungating fundus, develops. The lymphatic glands may become affected. The course of the disease is very chronic. In some cases deep gummata develop under the periosteum of various bones, and in the muscles. Large granulating ulcerations may form in the bucco-pharynx and larynx. The general health, as a rule, is not much affected.

Diagnosis.—In our experience, it is practically impossible in most cases to distinguish the affection clinically from lesions of tubercular, syphilitic, or frambœtic origin. The diagnosis is easily made by bacteriological methods. The simple microscopical examination of the pus of the abscesses, or scrapings of the ulcers, is not sufficient, as the fungus is extremely scarce. Cultivation must be resorted to. A few glucose-agar tubes are inoculated in the usual way, and kept at room-temperature without capping. After four to ten days the first colonies of *Sporotrichum* will appear.

Treatment.—Potassium or sodium iodides in full doses (15 grains three to four times daily) induce a rapid disappearance of all the lesions.

INTERTRIGO SACCHAROMYCETICA.

Synonym.—Intertrigo Blastomycetica.

Remarks.—Cases of this affection have been observed by Castellani in Ceylon, and one similar has been reported by Whitfield in England. The affection is apparently rare. It generally attacks the scroto-crural and axillary regions. The affected skin is red, and there may be slight exudation. The borders of the eruption are fairly well marked, but never elevated. In most cases there is not much itching, and the affection may recover spontaneously.

Ætiology.—In scrapings a Saccharomyces (*S. samboni* Castellani 1907), which is easily cultivated on sugar media, is found.

Treatment.—The treatment consists in washing the affected parts with potassium permanganate lotion, 1 in 4,000 ; resorcin, 1 in 100 ; followed by the application of powders of boric acid ʒi., talci ℥i. ; or salicylic gr. x., talci ℥i.

ASPERGILLOSIS AND PENICILLIOSIS OF HAIRY PARTS.

The affected hairs—generally those of the beard and moustache, occasionally of the axilla—present dirty greyish or whitish punctiform formations, which on microscopical examination are seen to consist of penicillar or aspergillar fungi (*Penicillium barbæ, Aspergillus barbæ*). Occasionally both types of fungi are found on the same patient. The affection is very chronic. The simplest method of treatment is by shaving, and afterwards using regularly a medicated soap, such as carbolic soap, tar soap, or sulphur soap. If the patient does not wish to shave his beard, turpentine may be tried.

In natives who do not bathe frequently, such as old persons and beggars, the skin presents often large dark patches due to accumulated dirt, in which aspergillar and penicillar fungi are often present, living saprophytically. This condition has nothing to do with pinta, as a thorough scrubbing with soap will remove the dirt and the aspergillar and penicillar fungi which may be present.

PINTA.

Synonyms.—Mal de los Pintos, Mal del Pinto, Caraate, Tina, Quirica, Pannus Carateus (Alibert), Tache Endémique des Cordillières (Alibert), Lota, Cativi.

Definition.—The term ' pinta ' does not indicate a single disease, but a group of closely allied dermatomycoses characterized by the presence of patches of various colour, due to different species of fungi of the genera *Aspergillus*, *Penicillium*, *Monilia*, and *Montoyella*.

History.—The disease first began to draw the attention of medical writers in the eighteenth century, though it was apparently well known to the inhabitants of the affected regions since remote times, as it is found to have formed the subject of prayers and supplications used by the Aztecs centuries before the Spanish Conquest.

A short description of the malady is found in the Encyclopædia of Polanko, of Mexico, in 1760 ; and in Juan de Velasco's 'Historia,' in 1789, in Columbia. Velasco believed the malady to have been imported by African slaves. A fairly complete description is given by Alibert, in 1829, under the name of 'tache endémique des Cordillières,' or 'pannus carateus.' Among the modern authors, the clinical and pathological investigation of Gomez, Uribe, Vribechyel, Iryz, Ruiz y Sandoval, Gastambide, may be mentioned.

More recently the investigation into the ætiology of pinta by Montoya has been of the greatest importance.

Climatology.—Pinta is practically limited to Tropical America, where it is found in Venezuela, Peru, Chili, Central American States, Mexico. Cases have been reported from Brazil. It is extremely common in Columbia, where, according to Montoya, 4 per cent. of the total population is affected. There the patient affected with the disease is called 'caratejo.' The disease is not equally distributed ; in each country there are localities where the disease is common, while other districts are almost unaffected. In Columbia it is the northern province of Santander which is more particularly affected ; in Mexico the disease is most frequently found in the provinces of Tabaxo, Chiaspas, Valladolid, Michoacan.

A few cases of pinta have been reported from Egypt by Madden, Goodman, and Sandwith, and previously Legrain described somewhat similar cases from Tripoli and the Sahara. Legrain, however, did not find any fungus. A few isolated cases have also been reported from the Gold Coast, and others from the Philippine Islands by P. G. Woolley. In Ceylon and India only imported cases are seen.

Ætiology.—Previously to Ruiz y Sandoval and Montoya's investigations the disease used to be ascribed to many different causes. Some authors believed it to be due to the mineral salts (sulphates) contained in the waters of the mines and other localities where the malady is endemic ; others considered it to be due simply to insanitary conditions, insufficient food, and a hot and damp climate ; others, again, believed the affection to be induced by the action on the skin of volcanic cinders ; while, according to some authorities, the malady was a hereditary complaint.

Ruiz y Sandoval, in Mexico, first detected the parasitic nature of pinta. He believed there was only one species of fungus to be found in the affection, and that the different colours of the patches were due to the different depth the fungus was growing in the various strata of the epidermis. Montoya's classical researches in 1898 clearly showed the plurality of species and genera of the fungi found in the disease, and demonstrated that each variety of pinta is due to a different fungus. More than twenty different species were found by him.

In the present state of our knowledge of pinta, it is impossible to give a satisfactory classification of these fungi. The principal ones may be collected into the following groups:

I. Fungi of genus *Aspergillus*: *Aspergillus pictor* Blanchard 1895, and several other species. *A. pictor* is found in the pure violet variety of pinta; the other species are observed in the pure blue and bluish and violet-black varieties, as well as in a form of the red variety. Several of these species are not in reality true *Aspergilli*, as they possess organs of fructification intermediate between those of the genus *Aspergillus* and those of the genus *Penicillium*.

II. Fungi of genus *Penicillium*: *Penicillium montoyai* Castellani 1907, and several other species. They are found in some greyish-violet varieties of pinta.

III. Fungi of genus *Monilia*: *Monilia montoyai* Castellani 1907. Found in some cases of white pinta.

IV. Fungi of genus *Montoyella*. *Montoyella nigra* Castellani 1907. Found in one variety of black pinta. *M. bodini* Castellani 1907. Found in a red variety of pinta.

The term *Aspergillus* (*Trichophyton*) *pictor*, introduced by Blanchard in 1895, when the plurality of species of the fungi found in pinta had not yet been demonstrated, is now used in a restricted sense to indicate the *Aspergillus* found in the pure violet variety of the disease.

Montoya believes that the fungi found in Columbian pinta, or caraate, are different species from those found in Mexican pinta.

Appearance of the Fungi in Fresh Preparations.—Scrapings from the patches examined in liquor potassæ show in most cases between the epithelial cells long dichotomous mycelial threads, from which shorter and thicker branches take origin at various points. These thicker branches terminate in comparatively large fructifications. The morphological characters of these fructifications vary according to the species and genus of the fungus present. They may be typical aspergillar or penicillium-like fructifications, or they may show intermediate characters between those of *Aspergillus* and *Penicillium*. In many cases the fructification organ is represented by a pear-shaped or triangular formation, surmounted by five to six rods (sterigmata), each of which supports a string of five to six spores. The number of these spores, however, may vary. They are globular, have a smooth surface, show a double contour, and their diameter is much larger than that of the mycelial tubes.

In the cases where the fungus present is a *Monilia* or a *Montoyella*, such or similar fructifications are absent, and only mycelial tubes and some scattered spores are seen.

Cultures.—The various fungi found in pinta are easily cultivated, the best medium being Sabouraud's maltose agar. The *optimum* temperature is between 30° and 40° Celsius.

The composition of Sabouraud's medium is:

Maltose	4 grammes.
Peptone (Chassaing)	1 gramme.
Agar	1·5 grammes.
Distilled water	100 c.c.

Culturally, the fungi may be divided in five groups;

1. Those showing in cultures aspergillar fructifications.
2. Those showing penicillium fructifications.
3. Those showing intermediate fructifications between the *Aspergillus* and the *Penicillium.*
4. Those showing simpler fructifications characteristic of the genus *Monilia*—viz., a mycelial thread terminating in a single string or small bunch of roundish spores.
5. Those in which higher organs of reproduction are absent, and reproduction takes place somewhat similarly to what is observed in the genera *Microsporon* and *Trichophyton*—by conidia and terminal segmented and unsegmented 'spindles.' The fungi of this group found by Montoya in a variety of black pinta, by Bodin, and later by Castellani, in a variety of red pinta, constitute the genus *Montoyella.*

Inoculation Experiments.—Montoya has tried to infect rabbits, using various cultures of the fungi found in the disease. On several occasions a desquamation of skin and loss of hair was observed, and some chromatic patches appeared. Uribe succeeded in inoculating several mulattoes.

According to Montoya, the fungi of pinta live saprophytically in certain waters, especially in those of mines and localities where the temperature is constantly high. He states that he obtained pure cultures of the pinta fungi direct from such waters. He has also found the same fungi as ectoparasites on the bodies of mosquitoes of the genus *Culex*, on sandflies (*Simulium*), and on the body of some bugs (*Cimex*) which are very common in the mines. He believes, therefore, that mosquitoes and other insects play a rôle in the transmission of the disease.

In some old chronic cases of pinta an *Acarus*—somewhat resembling *Acarus scabiei*, though larger—has been found to live in the epidermal squamæ, and some writers believe that this *Acarus* also plays a part in the transmission of the malady.

Predisposing Causes.—What the older authors believed to be the true causes of pinta—viz., a hot, damp climate; insanitary surroundings and poor feeding; the mineral salts contained in the waters—are only predisposing causes, some of which, however, are of great importance. The hot, damp climate favours the growth of the fungi; the water of the mines, which contains a large amount of mineral salts (especially sulphates), produces after a time in those who use it for washing, etc., a dermatitis with fissures and other eczematous-like lesions which greatly facilitate the infection.

All races are liable to be attacked by the disease, but mulattoes seem to be particularly prone to become infected. Albinos are said to be immune. Both sexes are equally liable to become infected, though males, on account of their occupations, are more frequently affected. The malady generally appears between the age of fifteen and twenty-five, but it may appear at any age, and has been seen in children three or four years old.

It has been observed that individuals of the negro race are more liable to contract the black variety than any other kind of the disease, while whites are especially liable to contract the red variety. Miners and agricultural labourers are affected in most cases by the violet variety.

Symptomatology.—The disease begins very gradually. After an incubation period, varying, according to different authors, between a few weeks and some months, one or several small slightly pruriginous spots appear on uncovered parts of the body. The spots increase very slowly in size, and some may fuse together. They are roundish, or may have an irregular outline. At first they are hardly raised above the normal skin. The surface of the patches is generally dry and rough, and is covered with fine pityriasic squamæ in recent cases, with larger and thicker scales in older ones. Occasionally, in chronic cases, the surface of the patches, instead of being dry, may be moist or somewhat greasy or glutinous.

The hairs of the affected regions become atrophied, and later on fall out. The shedding of hair is not due to the fungi invading directly the hair ; it is due to a peculiar fibrosis of the hair-follicle, at the place of the hair a hard formation remaining, like a grain of sand (fibroid folliculitis of Montoya).

Pruritus is generally well marked, especially at night-time. There are often patches of hyperkeratosis in the palms and soles, and the normal lines and sulci appear much deeper.

Old chronic cases occasionally exhale a peculiar musty odour, which has been compared to the smell of cat's urine, or to the bad smell of dirty linen kept in a warm, damp place.

The affection may spread to the whole body, except the palms of the hands and the soles of the feet. The nails are never attacked. The scalp is not usually affected.

The disease has no tendency to spontaneous cure. Its course is very chronic, and may last the whole of the patient's life.

Some of the older authors state that the patients during the incubation period suffer from fever, vomiting, and diarrhœa. Montoya says that pinta patients have not got an odour *sui generis*, as stated by most observers. In cleanly patients no smell whatever is felt, apart from the peculiar odour of the negro race.

Clinical Varieties.—Clinically, six different varieties may be distinguished, each of which shows several subvarieties :

1. The Black Variety.
2. The Blue Variety.
3. The Violet Variety.
4. The Red Variety.
5. The Yellow Variety.
6. The White Variety.

Black Variety.—The patches are of a black colour, and are very often found on the face, though they may be present on any other part of the body, except the palms and soles, similarly to all the other varieties. The patches are hardly raised, and their surface is slightly desquamating. Pruritus is generally complained of, but is not, as a rule, so unbearable as in the other varieties. Black pinta is found in negroes more frequently than in individuals of Caucasian race. The course is very chronic. The treatment is difficult, though not so difficult as in the other varieties.

Black pinta shows two subvarieties—one is characterized by the presence of patches of a black-violet colour ; the other by patches of jet-black, indian-ink black colour. The fungus found in the first is an *Aspergillus* (species undetermined) ; in the second a *Montoyella* (*M. nigra*).

Blue Variety.—This is much less frequent than black pinta. The patches are of a blue colour. They generally begin to appear first on the dorsum of the hands, and then tend to spread over the whole body—uncovered as well as covered parts. There generally is intense pruritus.

The fungus usually found in blue pinta is *Aspergillus*.

Violet Variety.—Apart from the colour of the patches, which is violet, the clinical symptoms and course of this variety are identical with those of blue pinta. It is extremely common among rural labourers and miners.

There are numerous subvarieties of violet pinta. In some cases the patches are of a pure violet colour ; in other cases the colour may be violet-greyish, violet-brownish, violet-purplish. There are cases in which the patches are at first of a greenish colour, to become violet-bluish later on. The fungus found in the pure violet pinta is an *Aspergillus* (*A. pictor* Blanchard 1895) ; the fungus found in the violet-greyish cases is a *Penicillium*—*P. montoyai* (Castellani) 1907 ; the fungi found in the other varieties are *Aspergilli* or fungi presenting transition characters between the *Aspergillus* and the *Penicillium*.

Red Variety.—This is the commonest variety found in white patients. The patches first develop, as a rule, on the dorsum of the hands and feet, and spread to large portions of the body. The patches are red—often brick-red—and usually show a rather abundant desquamation. Pruritus is very distressing, especially at night-time. Secondary lesions due to scratchings and inoculation of pyogenic micro-organisms are not rare. Ulcerative lesions have been reported by several observers as occasionally occurring.

In some cases of red pinta an *Aspergillus* (species not determined) is found; in others a fungus of the genus *Montoyella M. bodini* (Castellani) 1907, found by Bodin in 1903 in a patient who was under the treatment of Darier.

Castellani, in 1907, found the same or a very similar *Montoyella* in a case of red pinta observed in a European sailor who had long been in tropical America. In this case the disease had not yet spread much. Besides the red patches, there was on the right forearm a small greyish-violet spot, in which a fungus was found, which gave *Penicillium* fructifications in cultures (*P. montoyai*).

Red pinta is more serious than any other variety, as it affects not only the superficial strata of the epidermis, but the rete Malpighii as well as the corium.

Yellow Variety.—Very common among half-castes. It generally begins on the chest or arms. The patches are yellow, and at first are not pruriginous and not desquamating. In old cases, however, there is pruritus. This variety is very frequently mixed with patches of white pinta, and is difficult to cure. The fungi found belong to the genera *Monilia* and *Aspergillus*.

White Variety.—The patches are of a dull white colour, and are generally very large. The surface is usually rough and desquamating, but at times it may be smooth. In some cases a fungus of the genus *Monilia* is present, but, according to Montoya, in other cases no fungus whatever is to be found. Montoya considers the white variety of pinta to represent in many cases the ultimate retrogressive stage of all the other varieties except the red. The patches of white pinta would be in such cases in reality unpigmented, leucoderma-like areas due to the disturbing action of the various fungi on the pigmentation processes of the skin.

Montoya's belief on the nature of white pinta in some cases is supported by Castellani's observations on tinea flava and tinea alba. In both these dermatomycoses white, pseudo-leucodermic patches may occasionally be seen long after the fungus had died out, and these patches may remain unpigmented for months and years.

Mixed Variety.—Not infrequently the same patient may be affected with several varieties of pinta, presenting a grotesque tattooed or piebald appearance.

It is especially white pinta which is found associated with one or more of the other varieties.

Diagnosis.—This does not present any difficulty in the countries where the disease is endemic. In any doubtful case the microscopical examination, supplemented when necessary by the use of cultural methods, will clear the diagnosis.

Differential Diagnosis: Tinea nigra.—In contrast to the black variety of pinta, tinea nigra is very superficial, does not extend to large portions of the body, may attack the palms of the hands, is not pruriginous, is easily cured except when affecting the palms.

The microscopical examination of scrapings from patches of tinea nigra will show mycelial tubes of irregular shape and large globular spores collected in bunches. The spores are grouped together in a somewhat similar manner to what one sees in pityriasis versicolor.

Tinea flava.—In contrast to yellow pinta, the fungus of tinea flava is a Malassezia, has the same morphological characters of the fungus found in pityriasis versicolor, and cannot be grown artificially.

Tinea albigena and Tinea alba.—These are trichophytic affections, and are easily distinguished by the characters of the fungi.

Leprosy can be distinguished from white pinta lesions by the sensibility not being impaired in Pinta.

Only white pinta patches with no fungus might be mistaken for *leucoderma* on superficial examination. White pinta is very often associated with other varieties of pinta, which are easily diagnosed. Leucodermic patches are smooth, non-pruriginous, and the skin surrounding them is often hyperpigmented.

Prognosis.—Pinta, though not a fatal disease, must be considered a serious affection, as its course is chronic, and the treatment very difficult. In most cases the general health remains satisfactory, but the disfigurement is very distressing to the patients, who often become nervous and irritable. The pruritus, which is generally more marked at night, is also a cause of great distress and sleeplessness.

Treatment.—The popular treatment in Columbia is citrine ointment (mercury nitrate ointment). Other parasiticides have been tried, with a varying degree of success. When the eruption is at the very beginning, tincture of iodine may suffice. The best results have been obtained by using chrysarobin (chrysarobin, gr. x. to xxx.; ung. zinci ox., ℥i.). This must be applied cautiously. When the malady affects large tracts of the body, only a portion should be treated at a time, to prevent as far as possible symptoms of absorption. The urine should be regularly analyzed during the treatment. The chrysarobin ointment must not be applied to the face, lest a severe conjunctivitis should develop. For the face a resorcin, or resorcin-sulphur, or resorcin-salicylic, or salicylic acid ointment (resorcini, gr. xxx. to ʒi. ; ac. salicylici, gr. xv. ; vaseline, ℥i.), is advisable, or citrine ointment may be used.

Montoya recommends chrysarobin dissolved in chloroform (chrysarobin 10 parts, chloroform 90 parts). Apply with a fine brush. When dry, apply gutta-percha dissolved in chloroform (gutta-percha 10 parts, chloroform 90 parts).

Chrysarobin may conveniently be applied in the form of a vernisol varnish (5 to 10 per cent.).

PIEDRA.

Synonym.—Trichosporosis tropica.

Definition.—Piedra is a mycotic disease of some parts of South America causing small nodosities on the hair.

Remarks.—This disease of the hair is found in some districts of Columbia, especially the valleys of Canca; but closely allied conditions are observed in several parts of the tropics, and occasionally in temperate zones (*piedra nostras*).

Ætiology.—If an affected hair is washed in ether, and then treated with liquor potassæ, and examined microscopically, the nodules will be seen to consist of large polyhedric refringent bodies, held together by an amorphous substance acting as cement. These bodies are the spores of the fungus causing the disease (*Trichosporum giganteum* Behrend 1890). In Columbia it is generally believed that the infection takes place by washing the hair with a mucilaginous oil, much used by the women of the country.

Symptomatology.—The hair of the head of women, and less frequently the hair of the head and beard of men, is affected. The affected hairs present strings of pin-head-sized nodosities, which are better felt than seen. The nodosities may be very numerous, and are found on the surface of the hair-shaft, either on one side or surrounding it like a sheath. They are black and hard, though not so hard as the name piedra (stone) would imply, and a kind of crepitation is produced when the hair is combed. There is often matting and knotting of the hair. The disease is chronic, and the nodosities do not disappear spontaneously.

Diagnosis.—The microscopical examination of the nodosities renders the diagnosis easy.

Prognosis.—The affection is of long duration, and has no tendency to spontaneous cure.

Treatment.—This is difficult. It has been recommended to apply benzene and turpentine to the hair, and to wash the head regularly with a perchloride lotion (1 in 2,000). In obstinate cases it is necessary to shave the head.

Trichosporosis Indica.

In India and Ceylon a condition similar to piedra is occasionally observed. It is, however, much less severe, a few minute nodules only being present on the hairs of the beard and moustache, and the hair of the scalp being rarely affected The fungus seems to be different from that of the Columbian piedra.

Trichomycosis Nodosa Tropica.

This is common in Ceylon, and affects the hair of the scrotum and axillæ. The affected hairs present one or several hard, small nodules, which on microscopical examination show a prodigious number of rod-like organisms, easily stained with fuchsin. Cultures so far have failed.

Trichosporosis of Temperate Zones.

Cases of trichosporosis of temperate zones, or piedra nostras (tinea nodosa), have been described by Beigel (1869), Caro, Behrend, Unna, Pick, Villemin. The nodosities in such cases have been found on the hairs of the moustache and beard, not on the hairs of the head. The fungi are slightly different from *T. giganteum*. Several species have been described—*T. beigeli* Rabenhorst 1867, *T. ovoides* Behrend 1890, *T. ovale* Unna 1896.

Trichomycosis Nodosa of Temperate Zones.

Synonym.—Leptothrix; *T. palmellina* Pick.

This is found in temperate zones. The hairs of the axillæ and scrotum are brittle, and show numerous hard formations or concretions along the shaft. These concretions are resistant to strong alkalis, acids, chloroform, ether, benzine. Cocci and bacilli have been described by several authors.

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CHAPTER LVI

SKIN DISEASES (*continued*)—DERMATOZOIASES

General remarks—Creeping eruption—Circinate creeping disease—Cutaneous and subcutaneous myiasis—Dermatophiliasis.

Remarks.—Dermatoziasis in the wider sense of the word means any skin disease of animal origin, but the term is generally restricted to those dermatoses caused by animal parasites higher than protozoa. These skin diseases may be classified into the following groups:

I. *Due to Platyhelminthes—e.g.:*
    Sparganum proliferum.
II. *Due to Nemathelminthes—e.g.:*
    Filaria medinensis.
    Agchylostoma duodenale.
    Necator americanus.
III. *Due to Arachnida—e.g.:*
    Sarcoptes scabiei.
    Rhizoglyphus parasiticus.
    Demodex folliculorum.
IV. *Due to Hexapoda—e.g.:*
    Larvæ of various flies.
    Dermatophilus penetrans.

Most of the dermatozoiases have been mentioned in connection with the parasites which cause them (Chapter XX.), while others, such as scabies, cannot be considered as strictly tropical diseases, and hence cannot be dealt with here. It only remains to draw attention to the creeping eruptions, cutaneous myiasis, and dermatophiliasis.

CREEPING ERUPTION.

Synonym.—Larva Migrans.

This disease was first described by A. Lee in 1875. Later on, Procke, Blanchard, Topsent, Fülleborn, and others have recorded several cases. It is not rare in some parts of Europe, Africa, and Asia, and in South America. It is extremely rare in North America.

Ætiology and Pathology.—Larvæ of the genera *Gastrophilus*, *Œstromya satyrus*, *Hypoderma bovis*, and *H. lineata* have been found in several cases. In others no larva whatever was found. Looss states that the same clinical picture may be caused occasionally by agchylostoma and strongyloides (*Anguillula*) larvæ.

Symptomatology.—The eruption is characterized by the presence of a narrow raised red line, $\frac{1}{8}$ to 1 inch broad. This line extends daily one or several inches, and is generally sinuous, but may be straight. While the advancing end progresses, the opposite end slowly fades away. The duration of the malady is long—generally several months, but occasionally two or three years. There is much pruritus.

Treatment.—Hypodermic injections of various disinfectants have been tried with little success. Hutchins recommends a cocaine injection, followed by the injection of 1 or 2 drops of chloroform.

CIRCINATE CREEPING DISEASE.

In Ceylon cases are met with of a peculiar eruption, which is possibly of the same nature as the creeping disease previously described, though larvæ were not found.

The condition is characterized by the presence on the back of the hands of a ringed eruption, with markedly elevated, thick, angry, red borders. In all the cases the eruption started suddenly after the patient had been gardening and handling turf. There may be one ring or several. The skin inside the rings is normal. The rings expand eccentrically. The patients complain of the extreme irritation, and in all the cases stated that they felt something creeping along the red circles, as though a worm had got inside in handling the turf. The duration varies, but it generally does not exceed two or three weeks.

Ætiology.—The eruption does not appear to be a form of dermatitis venenata, due to touching certain plants and vegetables. Possibly it is due to some larva entering the skin, but so far the search for larvæ has been fruitless. No trichophyton-like fungus is present.

Treatment.—Liq. plumbi and other soothing applications are generally useless. The best results are obtained by continuously applying on lint a diluted alcoholic solution of resorcin:

Resorcin	ʒi.
Sp. rect.	℥ii.
Aq. dest.	ad ℥xii.

CUTANEOUS AND SUBCUTANEOUS MYIASIS.

Cutaneous and subcutaneous myiasis is the invasion of the skin and subcutaneous tissues by the larvæ of species of Diptera (Chapter XX.).

The genera and species which are commonly met with are *Dermatobia cyaniventris* Macquart, *D. keniæ* Kolb, *Cordylobia anthropophaga* Grünberg, *Dermatophilus penetrans* Linnæus.

DERMATOBIASIS.

This is the infection with *Dermatobia cyaniventris* or *D. keniæ*, and has been sufficiently described in Chapter XX., p. 551.

CORDYLOBIASIS.

Definition.—Cordylobiasis is the invasion of the skin and subcutaneous tissue by the larvæ of *Cordylobia anthropophaga* Grünberg (Tumbu-fly disease).

Remarks.—Recently several new and valuable papers on this affection, which is often called the 'Tumbu-fly disease,' have appeared, especially those by Austen, Smith and Blenkinsop in 1908.

Symptomatology.—The eggs are apparently sometimes laid on the clothing, the fly, perhaps, being attracted by the odour, or perhaps the larva wanders from the floor on to the human being, especially when using the latrine. The parts most affected are the thigh and buttocks in Europeans, but the forearm, axilla (especially in natives), and the head also may be invaded. The infected area presents the appearance of a boil, in the central portion of which there is an opening, more or less clearly defined, which is marked by black matter (the excrement of the larva). In this hole the posterior end of the larva may be noted, and on pressing on it considerable pain is produced, probably due to the movements of the larva. Surrounding the central opening is an inflamed area about ¾ inch in diameter. The opening may, however, be obscured by dried-up discharge.

Treatment.—Removal of the larva is very simply effected by seizing it by a pair of forceps and pulling it out.

DERMATOPHILIASIS (Jigger).

Definition.—Dermatophiliasis is the invasion of the skin and subcutaneous tissue by the pregnant female jigger (*Dermatophilus penetrans*).

Remarks.—The home of the jigger is in tropical America, from 23° N. to 28° S., but it and its wanderings over the world have been sufficiently described in Chapter XXI., p. 581. At present it is found in South America, West and East Africa, Madagascar, Uganda, India, and, it is said, China.

Pathology.—The pregnant female jigger pierces the skin obliquely near the nails and between the toes, but it may occur in any part of the foot, and even on the arms, scrotum, and face. All but the last two segments are embedded in the skin. These last segments plug the orifice, and discharge the eggs.

Symptomatology.—The symptoms begin with itching and irritation, generally in some part of the foot, especially the toes, and often under the toe-nail. On inspection, a small dark dot (the last two abdominal segments of the parasite) is noticed in the skin. If left alone, painful inflammation and suppuration develops around the distended abdomen of the parasite, giving rise to a swelling which may attain the size of a small pea, in the centre of which is seen a depression containing the black dot, and, finally, ulceration takes place, and the body of the parasite is thrown off, but not until all the eggs are laid.

When the parasite has been dislodged by treatment or suppuration, a small ulcer is left, which is very liable to septic or other bacterial infections. These infections may lead to phagedæna, gangrene, and tetanus. When the feet are badly affected, walking is impossible, which is of especial importance in carriers and native troops.

Treatment.—The treatment is the careful removal of the little insect with a clean needle, after rubbing weak carbolic ointment or lotion into the foot, and cleansing and dressing the little wound antiseptically.

Prophylaxis.—Prophylaxis consists in keeping the house clean, and pigs, poultry, and cattle kept away therefrom. High boots should be used, and especial care should be taken not to go to a ground-floor bathroom with bare feet. The feet, especially the toes and under the nails, should be carefully examined every morning to see if any black dot can be discovered, when the jigger should be at once removed, and in this way suppuration will be prevented. It is advisable, also, to sprinkle the floors with carbolic lotion, Jeyes' fluid, or with pyrethrum powder, or with a strong infusion of native tobacco, as recommended by Low and Castellani.

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CHAPTER LVII

SKIN DISEASES (*continued*)—ULCERATIONS

Oriental sore—Ulcus tropicum—Ulcus interdigitale—Ulcus infantum—Remarks on ulcers in the tropics—Granuloma inguinale—Papilloma inguinale—References.

ORIENTAL SORE.

Definition.—A specific circumscribed ulcerative affection of the skin caused by *Leishmania tropica* Wright.

The term 'Oriental sore' has been much abused in the past, and there is little doubt that different diseases have been described under that name. The term should be limited to those ulcerative processes of the skin in which *L. tropica* is found.

Synonyms.—Delhi Boil; Aleppo Boil; Biskra Boil; Bagdad Boil; Ulcera de Bauru (Brazil); Bouton d'Orient; Ulcère d'Orient; Chancre du Sahara; Dermite Ulcereuse Circonscrite (Corre); Endemische Beulenkrankheit; Botone d'Oriente; Godownik, *i.e.*, 'yearly boil' (Caucasus); the Tartar name is 'Il-jarassy' ('il' = year, 'jarassy' = boil); Tschiban, *i.e.*, 'yearly sore'; Dous-el-Kourmati, *i.e.*, 'date disease' (Turkish); Hhab-el-Seneh, *i.e.*, 'yearly boil'; Bess-el-Temür, *i.e.*, 'date disease' (Arabian); Salek, *i.e.*, 'annual' (Persian); Pascha-churdj, *i.e.*, 'fly-bite'; Afghan Jara, *i.e.*, 'Afghan plague'; Jaman Dyscharagan, *i.e.*, 'malignant ulcer'; Taschkent Jarassi, *i.e.*, 'Tashkent ulcer' (Tashkent); Mycosis Cutis Chronica (Carter); Lupus Endemicus (Lewis and Cunningham); Endemic Boil Disease (Scheube); Granuloma Endemicum (Brooke); Furunculus Orientalis (Crocker); Pian-Bois (Guiana).

The so-called Nile boil has been demonstrated by Modder to have nothing to do with Oriental sore, being of pyogenic origin. The so-called Bucharest boil, also, has apparently nothing to do with Oriental sore.

History.—The earliest account of the disease is to be found in Russell's description of Aleppo boil in 1756, in which he states that the inhabitants believed that it was caused by the drinking-water. The disease was also described by Hasselquist in 1762, Holland in 1780, Volney in 1787, Alibert in 1832, and Guillon in 1835. Tholozan, in 1866, appears to have been the first to doubt the ætiological value of the drinking-water; but Virchow is said by Hirsch to have been the first to suggest that the true cause might possibly be a parasite. The ætiology of the disease has been placed on a sound basis by the discovery of a Leishmania in the sores by Wright in 1903.

Geographical Distribution.—The disease is endemic in many tropical and subtropical regions. In Africa it is found in Morocco, Algeria, the Sahara (Biskra, Gafsa), Egypt; in Asia it is common in Syria and Asia Minor, in Mesopotamia, Arabia, Persia, the Caucasus, Turkestan (Tashkent), in the Turkmene district (Pendhe). It is very common in some parts of India, especially along the Valley of the Indus, in the Rajputana States, and in the North-West Provinces (Delhi, Multan, Lahore). In Europe the affection occurs in the Crimea, Cyprus, Crete. It is known also in Brazil and French Guiana, so that the name 'Oriental sore' is somewhat misleading.

It is generally much more common in large towns than in the country. In some cities it is so prevalent that even visitors of a few days only may not escape it. Its occurrence appears to be influenced by the seasons, as, according to Hirsch, in the tropics it is most prevalent at the beginning of the cool season, and in more temperate climates at the end of summer. Laveran says that in Biskra, from September to October inclusive, the slightest wound tends to become transformed into the 'bouton.' In some years it has been found to be more prevalent than in others.

A peculiarity of the geographical distribution of the disease is that in the countries where it is endemic its distribution is not general, but is confined to certain districts only; hence the numerous local names given to the malady, as Aleppo boil, Bagdad boil, etc.

Ætiology.—Smith in 1868 and Fleming in 1873 claimed to have found eggs of a species of *Distoma* in the sections of specimens of the tissues derived from cases of Delhi boil. Carter in 1875 described a mycelial fungus and spores. Depéret and Boniet, Duclaux and Heydenreich cultivated various cocci in 1884. In 1885 Cunningham described some peculiar parasitic organisms of various size and shape, often endocellular, easily brought in evidence by staining with gentian violet. Cunningham inclined to regard these bodies as representing various stages of the development of a mycetozoal parasite, probably belonging to the group of the Monadidæ.

Riehl (1886) isolated a capsulated micrococcus. Finkelstein and Chantemesse (1887) also cultivated a micrococcus similar to the organism described by Duclaux. Poncet in the same year described a coccus in sections and a very delicate bacillus. Le Dantec and Auché in 1894 found in a case of Biskra boil a streptococcus and the *Staphylococcus albus*. In 1897 Nicolle and Nourry Bey found a streptococcus which they believed to be specific. The organism was very slightly virulent. Attempts to inoculate monkeys with the disease did not succeed. In the same year Brocq and Veillon cultivated a streptothrix from a case of Aleppo boil. Crendiropuolo isolated in numerous cases a bacillus, probably belonging to the Proteus group. Firth in 1891 stated that he had been able to confirm the presence of the Cunningham parasitic bodies in numerous cases of Delhi boil. He proposed for the parasite the name of *Sporozoon furunculosum.* In 1898 Borowsky constantly observed in twenty cases of Sarten ulcer some peculiar organisms which he thought to be protozoa. In fresh preparations the bodies were very actively motile, and presented a spherical shape; sometimes they were spindle-shaped. The maximum diameter varied from 0·5 μ to 3 μ. The cell-body stained very faintly. The nucleus was placed eccentrically. No chromatin bodies could be put in evidence. Schulgin in 1902 confirmed Borowsky's results, and suggested that the disease might be conveyed by mosquitoes. In 1903, in a case of tropical ulcer occurring in a boy from Armenia, Wright described bodies very similar to those found in cases of kala-azar. These bodies may possibly be identical with those seen by Cunningham in 1885. Wright's discovery has been confirmed by Mesnil, Nicolle, James, Strong, Plehn, Nattan-Larrier, and others. Marzinowsky and Bogrow state that, independently from Wright, they found similar bodies in cases of Pendjeh ulcer from Persia.

Leishmania tropica (Wright) 1903.—Synonyms: *Helcosoma tropicum* (Wright) 1903, *Ovoplasma orientale* (Marzinowsky and Bogrow) 1904, *Leishmania wrighti* (Nicolle) 1908, *Crithidium cunninghami* (Carter) 1909. Common name: Wright-Cunningham body, Wright bodies. The parasite bears the greatest resemblance to *Leishmania donovani*—in fact, a distinction based on morphological grounds is practically impossible. The bodies are roundish or oval, 2 μ to 4 μ in diameter, with sharply defined outline.

In preparations stained with Romanowsky's method or the Leishman or Giemsa modifications of this method the bodies appear stained at the periphery, with a central portion unstained. They contain a spherical, rather large, purplish-stained nucleus towards one pole, and a smaller, often rod-like formation, also stained purplish, at the other pole. In films some of these bodies are free; others are embedded in the protoplasm of large mononuclear cells, with somewhat feebly stained nuclei (proliferated endothelial cells, according to Wright). Sometimes such cells contain as many as twenty or more micro-organisms. The developmental cycle of the parasite is not yet known. Nicolle first succeeded in cultivating it, using a medium composed of agar and rabbit-blood. The forms observed in cultures are practically identical with the cultural forms of *Leishmania donovani*, but according to Nicolle, the flagellum is somewhat longer, and undergoes early division. Nicolle and Siere have succeeded in reproducing the disease in a monkey by inoculating scrapings containing the parasite. Various authors have described the spontaneous occurrence of Oriental sore, or a very similar ulceration, in dogs, rabbits, camels, and other animals. Carter and Nattan-Larrier consider that there are several varieties of *L. tropica* producing similar but not identical clinical phenomena in man.

Mesnil, Nicolle, and Remlinger have observed the parasites to be present occasionally in true polymorphonuclear leucocytes, besides being found in the mononuclear leucocytes as usual. Mesnil has observed in some cases a typical 'bacillary' form.

The medium used by Nicolle for the cultivation of the parasite is composed as follows:

Agar	14 grammes.
Salt	6 ,,
Water	900 c.c.

This is dissolved in a large flask in a Koch's stove, and then distributed in tubes. After sterilization, to each tube is added one-third rabbit-blood, collected with all aseptic precautions. The tubes are kept aslant for twelve hours, then kept at 37° C. for five days, after which they are kept at the ordinary temperature for some days before using.

Histopathology.—The histopathology of the disease has been studied by Unna, Leloir, Kumm, Riehl, Wright, Strong, and by Bettmann and von Vasielewski. The histological lesions consist essentially in the atrophy and disappearance of the epidermis of the part and in a very extensive cellular infiltration of the corium and papillæ by various kinds of lymphoid cells, plasma cells, and numerous large roundish cells containing a single faintly stained vesicular nucleus and large amount of cytoplasm. These large roundish cells, which are probably proliferated endothelial cells, contain often many of Wright's bodies closely packed together, occupying most of the available space between the nucleus and the cell periphery.

Communicability.—The disease may be conveyed by direct infection from person to person, by absorption of the virus through some pre-existing abraided surfaces, or small wounds or ulcers of other nature present on the skin. Insects, especially flies, probably play a certain rôle in the transmission of the disease. That flies convey the disease was first claimed by Seriziat (1875) and by Tscherepkin (1876).

Tscherepkin states that by the people of Tashkent the disease is called 'pascha-churdj,' meaning 'fly-bite.' Laveran thinks that flies carry the virus on their feet and proboscis, and thus convey infection. Schulgin believes the disease to be conveyed by mosquitoes. Ed. Sergent and Pressat have suggested that some 'Phlebotomus' may play a rôle in the transmission of the disease.

The disease is inoculable from man to man, as is clearly proved by the experiments of Marzinowsky. It is also auto-inoculable.

Marzinowsky inoculated himself with Oriental sore by putting inside the bulla caused by an artificial burn on his hand some material (scraping) derived from an Oriental sore. After ten days from the inoculation he began to feel unwell and feverish, and suffered from headache and general debility. The fever lasted two weeks. With the beginning of these general symptoms a papule appeared at the seat of inoculation, which slowly developed into a typical Oriental sore. Scrapings contained many parasites. The Bagdad Jews, according to Colvilli, inoculated their children with the disease, as they thought that after having got over it once, there was no danger of getting it again.

Symptomatology.—One or several small pruriginous spots appear on the skin of uncovered parts of the body, not much dissimilar at the very beginning from mosquito-bites, for which they are often taken by the patients. The spots, however, instead of slowly fading, become red and shotty, with an inflamed areola, which later becomes markedly indurated. The papules slowly enlarge to the size of a pea or bean ; the surface gradually loses its smooth and shiny appearance, and becomes covered with small thin scales. After a period of time, somewhat variable in length, but generally not exceeding three to four months, the ulceration of the nodule begins. At first the ulceration is very superficial, and exudes a yellowish secretion, which soon dries into a hard, adherent, darkish scab. Underneath the scab the ulcerative process and disintegration of the nodule continues slowly to spread. The tissues surrounding the ulcers may become œdematous. If later the darkish scab be removed, an ulcer is seen, about an inch or more in diameter, with sharp-cut, jagged edges and irregular fundus, with reddish-yellow, sometimes fungating granulations. The ulcer is generally indolent, or but slightly painful. The neighbouring lymphatic

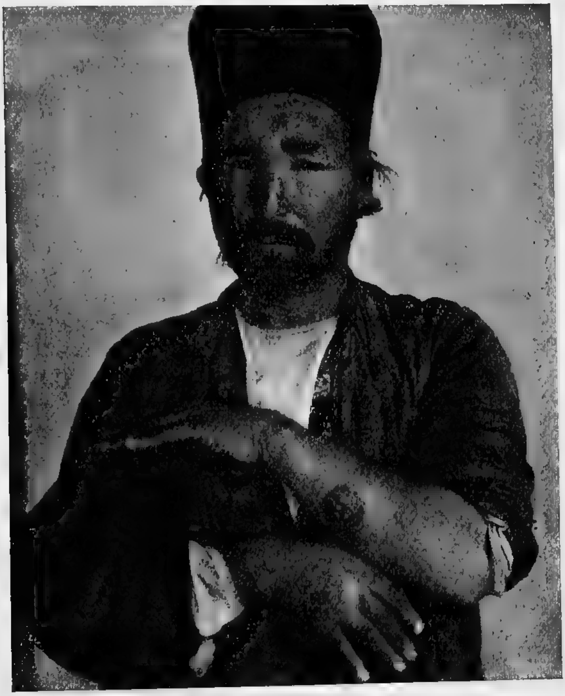

FIG. 359.—ORIENTAL SORE IN A PERSIAN SOLDIER.

(From a photograph of Drs. A. Bassière and Nattan-Larrier.)

glands are not, as a rule, sensibly enlarged, unless there is a secondary pyogenic infection. The examination of the blood shows a distinct mononucleosis.

Healing generally sets in after six to twelve months by granulation, which begins in the centre of the ulcer, the unhealthy-looking, large, yellowish granulations giving place to healthy ones. A whitish or pinkish, often depressed and disfiguring, scar remains at the seat of the ulceration. After cicatrization, the sore may break down again.

Oriental sore may be single or multiple. Two or three are frequently found on the same patient, but occasionally there are many more. The sores are auto-inoculable by scratching.

The seat of the ulcers is generally on uncovered parts—feet, legs, hands, arms, face. They are very seldom observed on the palms, soles, or scalp. The affection attacks people of any race, sex, and age, if they expose themselves to the infection.

Course.—The length of the incubation period is not known with certainty. It is generally stated that it varies between a few days and six weeks. Manson, however, has observed that it may be as long as five months. In one case he made the interesting observation that the appearance of the sore was preceded several months by a fever of an irregular remittent type, not influenced by quinine, and having some features of the fever of Indian kala-azar. Attacks of irregular fever during the incubation and the course have been recorded by several authors. During one of these febrile attacks Neumann observed *L. tropica* free in the liquor sanguinis of the patient.

The duration of the eruption varies from four or five months to twelve months and more. Repeated attacks of the disease often occur.

Diagnosis.—In countries where the affection is endemic the diagnosis in most cases is not difficult. The following are the principal data on which to base the diagnosis :

1. The fact that the patient comes from, or has been living in, an affected area.
2. The few eruptive elements—often one single element—situated on uncovered parts.
3. The course : a small papule, which slowly enlarges into an indurated nodule, and after several months ulcerates.
4. The proximal lymphatic glands are not enlarged.
5. Presence of *Leishmania tropica.*

The history, the absence of enlarged lymphatic glands, and other symptoms of syphilis, and the uselessness of the mercurial treatment, will help in excluding syphilis. In frambœsia there is a primary sore, which, after a time, is followed by a general granulomatous eruption. We have, however, seen cases of frambœsia patients who, after the general eruption has disappeared, have remained for months with a single or a few sores closely resembling the Oriental sore. In fact, we believe that in a certain number of cases it is very difficult to make the differential diagnosis between Oriental sore and ulcers of tubercular, syphilitic, or frambœtic origin; also from cancroid when the ulcer is single and situated on the face. In our experience, the only reliable way to come to a definite diagnosis in difficult cases is the microscopical examination. To do this the scab is removed, and a scraping is taken from the floor and edges of the ulcer. The preparation is then coloured with Leishman's or Giemsa's stain, or any other of the numerous modifications of Romanowsky's method, and examined for the presence of *Leishmania tropica*. The search must be prolonged in some cases, as the parasites may be very rare.

Prognosis.—The prognosis is good, *quoad vitam*. Very occasionally the disease may end fatally, owing to the ulcers becoming phagedænic, and to secondary septicæmic and pyæmic processes. Sometimes the scars remaining after the ulcers have healed up shrink considerably, and if they are on the face, may give rise to serious disfigurement.

Treatment.—The treatment of Oriental sore is very unsatisfactory. Nitrate of mercury ointment, alum ointment, boric acid, and various other antiseptics have been recommended, with very poor results. Formalin often irritates the ulcer, and may produce a dermatitis. Röntgen rays have been tried, without any good result. An expectant treatment is generally to be advised. The scabs should be removed by boracic acid fomentation and then the sores must be thoroughly disinfected once or twice daily with a 1 in 1,000 solution of perchloride of mercury or 2 per cent. carbolic acid, after which one of the ordinary antiseptic ointments (β-naphthol, gr. v.; vaseline, ʒi.; iodoform or europhen, gr. v.; ung. ac. borici, ℥i.) or an antiseptic powder (iodoform or xeroform or boric acid) is applied.

Marzinowsky, after removing the crust, and cleansing the ulcer with antiseptic lotion, applies a 10 per cent. lotion of ferropyrin to stop the bleeding, and then applies thoroughly a 50 per cent. lotion of chininum bimuriaticum daily. He says recovery takes place in between seven to eleven days.

Schulgin advises the freezing of the boil with ether. He used this method in 300 cases with good results.

Several French writers advise the use of permanganate of potassium, at first in powder form, and later as a 5 per cent. ointment.

Duncan advises placing a thin piece of lead over the ulcer, and then bandaging up.

Emily recommends the repeated applications of boric acid.

Ondiourminsky has applied to the treatment of Oriental sore Bier's stasis method, apparently with good results.

Chulguine recommends soaking the sore with a solution of methylene blue (10 per cent.).

Bussiere advises dilute tincture of iodine (10 per cent.).

In other cases Bussiere and Nattan-Larrier advise excision of the sore. Several physicians praise the use of silver nitrate.

Castellani had some fairly good results in two cases by washing the sores with a 5 per cent. solution of protargol, followed by the application of a 20 per cent. protargol ointment. The protargol ointment cannot be used on Europeans when the face is affected, as the protargol, after some time, induces a discoloration of the skin.

Prophylaxis.—The disease being very contagious, and being also probably spread by some blood-sucking insects, the slightest wound and any insect-bite should be thoroughly disinfected with carbolic acid 5 per cent., or tincture of iodine 10 per cent.

ULCUS TROPICUM.

Synonyms.—Yemen Ulcer, Aden Ulcer, Annam Ulceration, Cochin Sore, Mozambique Sore, Sarmes (Congo), Tropische Phagedenismus (German), Ulcère Phagédénique des Pays Chauds (French), Ulcère Phagédénique Endémique (French), Ulcera Tropicale (Italian), Phagedæna Tropica.

Definition.—Ulcus tropicum is a tropical chronic sloughing ulcer, which may take a phagedænic character, and spread down to the muscles and bones, and which, left to itself, has hardly any tendency to healing.

History.—Phagedænic ulceration is mentioned in many of the early works on tropical medicine. Thus, Hunter in 1792 refers to it in Jamaica in the following terms:

'Sores . . . spread quickly, and form large ulcerated surfaces. . . . The granulations turn flaccid, and even mortify in parts. The portion skinned over ulcerates afresh, and the sore becomes larger than ever. Ulcers of some standing . . . could not be healed in that country. . . . Opportunity was taken to send home men with ulcers.'

After this date there are numerous references to the complaint, which is generally described under the name of the locality in which it was found, which accounts for many of the above synonyms. In 1862 Rochard took a broader view of the disease, and in 1864 Le Roy de Méricourt introduced the term 'Phagedænic ulcer of warm countries.'

In 1874 Treille suggested that the disease was likely to prove to be of a parasitic origin, but he failed to demonstate any parasite. Bacteria have since been described by many observers, and more recently spirochætes have been considered to be the cause of the disease, as will be described in the section on Ætiology.

Climatology.—Ulcus tropicum is found in all tropical and subtropical regions of Africa, Asia, and America. There are localities, however, such as the hinterland of Aden, the low, marshy plains of Cochin-China and Tonkin, and some islands of the Red Sea, where the affection is particularly common.

Ætiology.—Numerous bacteria have been described by Petit, Boniet, Le Dantec, Blaise, Crendiropoulo, as being the cause of the disease. Vincent believes the affection to be due to the association of spirochætes and fusiform bacilli so frequently found in such ulcers. Vincent's observations have been confirmed by Smith and Peil in Sierra Leone, Patton in Aden, and many other observers in various parts of the tropics. Prowazek has recently fully described as cause of the disease a spirochæte which he named

Spirochæta schaudinni. The important researches of Keysselitz and Mayer tend to confirm Prowazek's work.

Spirochæta schaudinni (Prowazek) 1907.—This is a spiral-shaped organism, very actively motile, its length varying between 10 μ and 22 μ, though much shorter or longer individuals may be met with. The coils are few in number, and elongated. The organism possesses a well-marked undulating membrane, which is best brought into evidence by using Löffler's flagellar stain. A delicate, rather short flagellum is occasionally seen at one of the extremities. Forms undergoing longitudinal division are frequently observed. Prowazek distinguishes, also, male and female forms. Variously shaped regressive and rest forms may be seen. According to Prowazek, *Spirochæta schaudinni*, apart from being more slender, has the greatest resemblance to the spirochæte which Prowazek himself and Hofman have described in a form of balano-posthitis.

According to Le Dantec, Brault, Vincent, and others, ulcus tropicum is identical to the so-called ‘ hospital phagedæna ’ which used to rage in hospitals of all countries before the antiseptic era. In our opinion, ulcus tropicum is a separate disease, though occasionally, owing to secondary infections, it may take phagedænic characters similar to those found in hospital gangrene.

Inoculation Experiments—Communicability.—Experiments to inoculate the disease in men and in the lower animals have been made by several authors. Blaise inoculated himself with the secretion of a case of ulcus tropicum, but no ulcer was produced—only a slight superficial, purulent lesion, probably due to pyogenic cocci present as secondary infectious agents in the secretion which had been used for the inoculation. Blaise tried to inoculate the disease, also, in guinea-pigs, but without any sure result. Similar experiments on the lower animals by Jourdeuil and Gayer failed. Recently Halberstädter tried to reproduce the affection in monkeys (ourang-outang and *Macacus cynomolgus*), but without success.

It would seem, therefore, that, to a certain extent, the disease is not directly contagious. It is probable that some insects or other blood-sucking vermin may play an important rôle in the transmission of the disease. In Ceylon, patients often state that the ulcer developed at the site of a leech-bite. Leeches are extremely common in Ceylon and other tropical countries. Prowazek in Java has examined many leeches, but he never found any spirochæta except once. The spirochæte observed, however, was quite different from *Spirochæta schaudinni*. Prowazek examined, also, on many occasions the mud of rice-fields, but of spirochætes he found only *S. plicatilis*, and once a very thin, short, very actively mobile spirochæte.

Predisposing Causes.—A hot damp climate is said to have a predisposing influence, as cases of ulcus tropicum occur more frequently in the hot rainy season and marshy lowland localities rather than in dry or higher regions. It may be that it is in hot, marshy places that the carriers of the infection thrive.

The disease is very common among the poorer classes of the population, who go barefooted, and wear but scanty clothes. We have observed it very often in beggars and in scabies patients. The disease is much more common in adults than in children, in men than in women.

Histopathology.—On microscopical examination of vertical sections of the ulcer, it will be seen that the superficial layers of the fundus show a large amount of granular detritus and numerous foci of leucocytic infiltration, while the deeper layers consist of fairly dense fibrous tissue. Hæmorrhagic foci are to be seen in various parts, and as observed by Keysselitz and Mayer, fusiform bacilli and spirochætes are found in the superficial layers, while in the deeper strata only spirochætes are present.

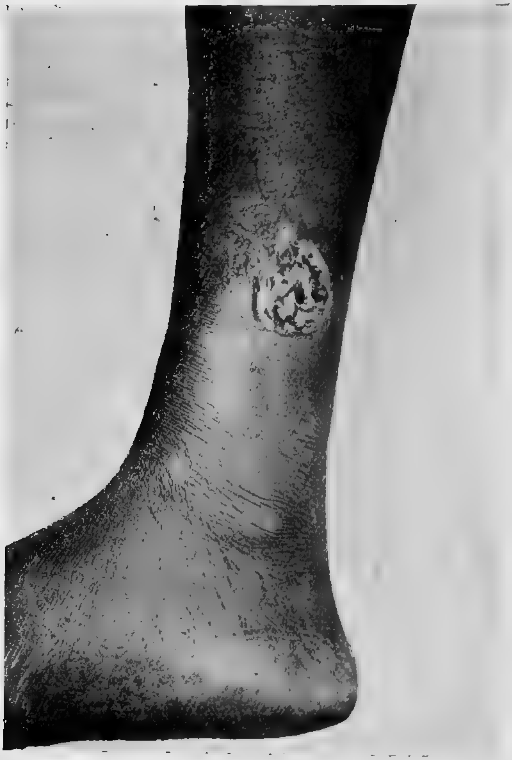

FIG. 360.—ULCUS TROPICUM (TYPICAL).

Symptomatology.—The affection is generally found on the lower limbs, especially the lower third of the leg, the ankle and dorsum of the foot. Occasionally it may develop on other uncovered parts of the body. It is single in most cases, but two or more ulcers may be found in some patients.

Ulcus tropicum begins with the appearance of a small, painful, occasionally pruriginous papule or papulo-pustule, surrounded by a deeply infiltrated dusky red areola. The initial lesion soon undergoes purulent and degenerative changes, which rapidly extend to the infiltrated area. A sloughing process sets in, and an ulcer is formed, which gradually extends in depth and surface. The margins are not sensibly raised, nor thickened, unless the case be very old. They are not perpendicularly cut, nor undermined, as a rule, the whole ulceration having generally a roundish or oval outline, and when the secretion is removed a concave fundus. The parts surrounding the ulcers are often œdematous, and somewhat painful on pressure. It is remarkable, however, how comparatively little pain there is in many cases.

When the patients are first seen, the whole ulcer is generally covered with a thickish, dirty greyish secretion, exhaling a highly offensive odour. On removing the secretion, the fundus will be found to be of a red colour, or in chronic cases pale pinkish, and feebly granulating.

The fundus is often somewhat infundibular in its central area, and not rarely may present a circular raised ridge, which divides the ulcer into two portions—an external more superficial one, and an internal infundibuliform one.

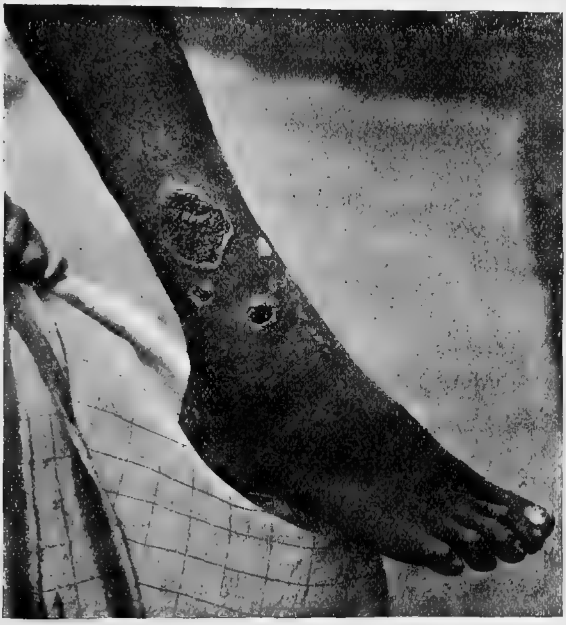

FIG. 361.—ULCUS TROPICUM.

Occasionally, if left untreated, the ulcer may take a real phagedænic character, involving a large surface, and deepening till the deeper structures—muscles, tendons, and periosteum—are affected.

The course is always chronic, lasting for months—in fact, the ulcer has hardly any tendency to spontaneous healing if untreated. Healing takes place by a very slow process of granulation, and begins from the periphery. A thick, whitish, often disfiguring scar is left at the place of the ulcerations. At times, however, the cicatrix is at first very delicate, and the ulcer may break out again after the least irritation.

The microscopical examination of the greyish, bad-smelling secretion shows leucocytes undergoing various degenerations, some red-blood cells, threads of connective tissue, and very often spirochætes and fusiform bacteria, of various types, sometimes accompanied by the usual pyogenic cocci. In old untreated cases larvæ of flies may be found, small Acarids, and ants.

Diagnosis.—According to Le Dantec, Vincent, and several other observers, ulcus tropicum is identical with 'hospital phagedæna.' The fact, however, that, in contrast to 'hospital phagedæna,' ulcus tropicum shows very little or no direct contagiousness, and in most cases is self-limited, clearly shows, in our opinion, that the two are separate diseases.

Differential Diagnosis—Frambœsia.—The lesions in frambœsia are generally multiple—either granulomatous or ulcerative. Scrapings from frambœsia lesions—after the superficial strata have been removed—will often reveal the *Treponema pertenue,* which is much more slender than any of the spirochætes found in ulcus tropicum. Occasionally an ulcerative frambœsia lesion may become infected with the virus of ulcus tropicum. In our experience, however, the reverse is much more common—viz., an ulcus tropicum becomes infected with frambœsia virus, takes a papillomatous appearance, and is followed by a general eruption of frambœsia granulomata.

Syphilis.—Ulcus tropicum does not show the clean-cut margins of a tertiary ulcer. The specific treatment has no influence on it.

Oriental Sore.—An old-standing Oriental sore may present some characters of a chronic ulcus tropicum, though generally a tropical ulcer is much larger. In such difficult cases the search for *Leishmania tropica,* which is present in Oriental sore, will clear the diagnosis.

Ulcers of Tubercular Origin.—They are rare on the lower extremities, and their development is long and insidious. In ulcus tropicum the tubercular cuti and ophthalmic reactions are negative unless the ulcer develops in a tubercular patient.

Blastomycosis—Sporotrichosis.—In blastomycosis there are generally warty patches with minute abscesses; while the lesions of sporotrichosis often show at first the characters of gummata. The bacteriological examination will reveal the presence of the fungi.

Mycosis Fungoides.—Is generally preceded by a general pruriginous dermatitis of various character, lichen-planus-like, psoriasis-like, eczematous-like. The ulcerative lesions are multiple, and have the characters of granulomata.

Prognosis.—If untreated, tropical ulcer has very little or no tendency to spontaneous recovery, and in some cases may extend, damaging the deeper structures, tendons, muscles, nerves, and vessels. Occasionally a general septicæmia and pyæmia may supervene. In countries where frambœsia is endemic the ulcer often gets infected with its virus, and the patient develops a general eruption of frambœsia.

Treatment.—The patient must be kept at rest, the dirty, greyish, foul-smelling secretion removed by using a disinfecting solution, such as mercury perchloride, 1 in 1,000 ; cyllin, 1 in 300 ; hydrogen peroxide, 10 per cent. ; permanganate of potash, 1 in 2,000.

For the first few days it is better not to apply any so-called disinfectant ointments or powders : simply keep the ulcer covered with gauze, moistened as often as possible with one of the disinfecting solutions already mentioned. This generally stops the formation of the greyish, dirty secretion. The ulcer will then appear clean and of a pinkish colour ; but whatever be the further treatment used, whether powders (iodoform, boracic acid) or disinfecting ointments (white, red precipitate, or iodoform ointments), the improvement will be very slow, and several weeks, and often months, will elapse before a firm cicatrix is formed. Much quicker results will be obtained by using a protargol ointment. The ulcer is cleaned every morning with a perchloride lotion (1 in 1,000) ; then a protargol ointment (5 to 10 or 20 per cent.) is thickly spread on a piece of lint or gauze and applied to the ulcer, which is then fairly firmly bandaged.

The superiority of the protargol treatment is patent in many cases. Castellani, who introduced it for ulcus tropicum, made the following experiment : In a patient presenting two ulcers of little difference in size and deepness, one on the right leg, one on the left, he treated the one on the right leg, which was slightly larger and deeper, with protargol, and the one on the left leg with iodoform. The ulcer treated with protargol healed in three weeks, the one treated with iodoform in two months.

ULCUS INTERDIGITALE.

This affection is common among natives of Ceylon. The patient complains of some itching between the toes, though no papules or vesicles are seen. After a few days a fissure appears, which rapidly deepens, and enlarges into a large oval ulcer with a dull, dark red fundus and sodden-looking margins. There is practically no discharge whatever. The ulcer is generally very painful. The skin surrounding the ulcers does not show signs of inflammation. Under proper treatment the ulcer heals in a few days. The patient must remain at rest, washing the ulcer twice daily with a 1 per cent. carbolic lotion, followed by dressing with a bismuth-boric acid ointment :

Bismuth subnitratis	gr. xxx.
Acidi borici	gr. xv.
Vaseline	℥i.

ULCUS INFANTUM.

Under this name Castellani has described a rather rare ulcerative condition of the legs met with in Ceylon among children, both native and European. A reddish spot appears on some part of the leg. The spot becomes slightly elevated, and shows a yellowish central point. The yellowish point breaks down, and a small ulcer appears, generally of circular shape, and with a red fundus. The ulcer secretes a yellowish, thickish secretion, which dries into a yellow crust. If after some days the crust is removed, the ulcer will be found much larger and deeper—the size of a shilling to a half-crown piece. The ulcer is generally indolent, except on pressure. There may be a little pruritus. The ulcer may be single or multiple. The inguinal lymphatic glands may become enlarged, and occasionally the child has fever. The duration is between four to six weeks and three or four months. On healing a permanent whitish scar is left.

Ætiology.—This is unknown. A bacillus which cannot be grown is the only germ present in most cases; but as to its ætiological rôle nothing can be said definitely.

Diagnosis. — The ulcus infantum is differentiated from ulcus tropicum by the less severe symptoms by being almost always multiple, by the smaller dimensions of the sore, by the absence of spirochætes, and by the absence of any tendency to phagedena. In contrast to veldt sore the ulcers are deep, and the crust very thick. No streptococcus is found.

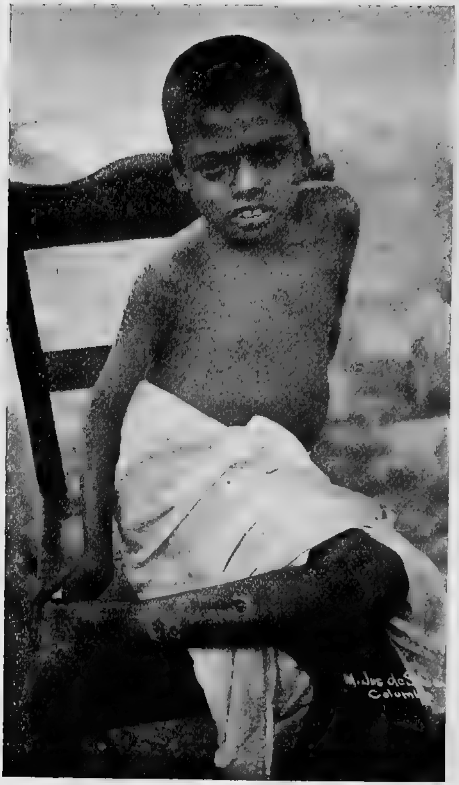

Fig. 362.—Ulcus infantum.

Treatment.—Touch the ulcers with pure hydrogen peroxide once every other day, and dress them with simple boric acid lotion (2 per cent.).

REMARKS ON ULCERS.

Ulcerative conditions of the skin are extremely common in the tropics. They may be classified as follows:

1. Oriental sore.
2. Ulcus tropicum.
3. Ulcus infantum.
4. Veldt sore.
5. Ulcus interdigitale.

6. Gangosa ulcers.
7. Leprotic ulcers.
8. Ulcers of frambœsial origin.
9. Elephantoid ulcers.
10. Blastomycetic and sporotrichetic ulcers.
11. Cancerous and sarcomatous ulcers.
12. Tubercular ulcers.
13. Syphilitic ulcers.
14. Glanders ulcerations.
15. Ulcers of pyogenic origin (pyosis tropica).
16. Ulcers due to varicose veins.
17. Undetermined chronic or subchronic ulcerations.

The ulcerative conditions which may be considered as strictly tropical and well defined, such as Oriental sore, ulcus tropicum, etc., have already been described. The cosmopolitan ulcerations, such as the syphilitic ones and those due to varicose veins show the same characters in the tropics as in temperate zones, except that very often, owing to their being neglected for a long time, they may present enormous dimensions, and may show secondary infections, and become phagedænic. Ulcers due to varicose veins are very common among rickshaw coolies, who have to run and stand for hours at a time. It is remarkable how quickly they heal in most cases in these coolies if the patient is kept at rest for some time; whereas in temperate zones the healing of varicose veins ulcers is of very long duration.

Undetermined Subchronic and Chronic Ulcers.

Knowledge of this group of ulcers is scanty, but the investigations of Strong, Stitt, Rho, Wherry, and Clegg and others have thrown some light on this subject. Our experience tallies with that of Stitt, and we therefore consider that such ulcers may be roughly divided into three groups:

1. Septic Ulcers—Ulcerations following on Neglected Wounds.
2. Painless Chronic Ulcers.
3. Diphtheroid Ulcers.

Septic Ulcers—Ulcerations following on Neglected Wounds.—These are of pyogenic origin and often very large dimensions. They are generally of roundish or irregular shape, and may be very deep. The secretion is abundant, purulent, and contains the various staphylococci. If the pus is removed, and a scraping taken from the fundus, the preparation will show numerous polymorphonuclear leucocytes and various cocci. These ulcers do not show tendency to spontaneous cure, but heal quickly under an antiseptic treatment. We generally treat them with hydrargyrum perchloride (1 in 2,000). The opsonic treatment also gives good results.*

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* Nichols has called attention to discharging sores in the Philippine Islands, called 'puente,' which are produced by the natives applying some lime to the skin, and afterwards betel-powder, with the object of counter-irritation.

Painless Chronic Ulcers.—A small red scaly, slightly itching spot appears, generally on the legs, and gradually enlarges for about four to eight weeks, when the affected area begins to exude a serum which quickly dries into crusts. Under the crust ulceration slowly takes place. At first the ulcers are shallow, and may have undermined edges; later they are often punched out, and may become indurated. There is no pain, except slight pain on pressure, and the general health is not affected. Healing takes place under the crust, and lasts between two and twelve months. A pale cicatrix, with hyperpigmented margins, is left.

As noted by Stitt, scrapings from the fundus show a prevalence of mononuclear cells, polymorphonuclears being practically absent. No pyogenic organisms are found.

Treatment.—The treatment is difficult. Cauterization does very little. In some cases the application of bismuth subnitrate, xeroform, dermatol, and firm bandaging is useful. In others a protargol ointment (5 to 10 per cent.) is of advantage. When the ulcers are very large and atonic, skin transplantation may be necessary.

Diphtheroid Ulcers.—An angry red, painful spot, often surrounded by vesicles, appears on the legs. Within a few hours—twelve to forty-eight—the affected area is turned into a dark greyish or blackish membrane. If this membrane be removed, an ulcer will be found, covered with greenish pus. The membrane reforms rapidly, and, apart from the dark colour, it closely resembles a diphtheria membrane. These ulcers extend rapidly, but do not take, as a rule, a true phagedænic character. The margins after some time may become indurated, but do not show a punched-out appearance. Scrapings taken from the fundus show numerous polymorphonuclears. The course is very long. These ulcers are with difficulty distinguishable from true ulcus tropicum except by the absence of *S. schaudinni*.

Treatment.—Excision is not to be advised, as in Stitt's and our own experience, when this has been done, additional lesions have appeared. Bier's passive congestion method is painful, and does not improve the condition. On the whole, the best treatment is to keep the ulcers well disinfected with a perchloride lotion (1 in 2,000), occasionally touching them with pure hydrogen peroxide. Should the ulcers become phagedænic, the application of pure carbolic is advisable.

GRANULOMA INGUINALE.

Synonyms.—Ulcerating Granuloma of the Pudenda, Granuloma Venereum (Brooke).

Definition.—Granuloma inguinale is a chronic granulomatous affection of probable spirochætic origin attacking the generative organs, from which it spreads to the inguinal region and the perinæum.

History.—In 1896 Conyers and Daniels described a disease of the generative organs in both men and women in British Guiana which was very painful, disfiguring, and contagious. Daniels thinks that it was previously described by Macleod and Maitland in India. Since then papers have appeared on the subject by Ozzard, Galloway, Wise, and others.

Climatology.—It occurs in British Guiana, the West Indian Islands, West Africa, India, South China, and Australia; but is rare in Ceylon, Malaya, and Central Africa. A similar or identical condition has rarely been met with in Europe.

Ætiology.—It appears in the genitalia of both sexes after puberty, but is rare after forty-five years of age. It is not syphilitic, nor is it malignant. Neither is it tubercular, as injections into guinea-pigs do not produce tuberculosis.

Wise in 1907 found in the eruption spirochætes resembling *Treponema pallidum* and *Spirochæta refringens*, together with some small bodies consisting of a thin capsule surrounding a clear unstained space, in the middle of which was a curved chromatic rod, which was thinner in the centre, and club-shaped at either end. He found from two to twenty-five of these in leucocytes. Donovan has described small, rod-like parasites 2 μ by 1 μ, with elongated nuclei, which lie singly or in groups in mononuclear cells obtained by scraping the sores. Cleland has confirmed Wise's observations, and has called the spirochæte *S. aboriginalis* Cleland 1909.

The disease is generally transmitted by sexual intercourse. Cleland states that in West Australia the disease is especially prevalent among 'gins' (native women), and there is an idea present among the white settlers that the girls become infected by connection with dogs, which, however, is open to considerable doubt, though it is well known that dogs may suffer from granulomatous tumours in which spirochætes have been found by several authors.

Pathology.—According to Galloway, the microscopical changes begin some distance from the lesion, and consist of a round-celled infiltration into the upper regions of the corium. This induces the papillæ to increase in length, thus producing the typical papule, and at the same time causes an elongation of the interpapillary processes of the epidermis, until they are some eight or ten times their original length.

The connective tissue of the corium swells and disappears, and its place is taken by a round-celled infiltration, which consists of leucocytes, Unna's plasma cells, mast cells, and connective-tissue cells. The leucocytes are the ordinary polymorphonuclear leucocytes, while Unna's cells are characterized by possessing a rounded nucleus, with a certain amount of surrounding protoplasm containing basophile granules. The connective-tissue cells are spindle-shaped. The cells of the epidermis are modified over the papule by becoming swollen, hyaline, and showing mitosis. The stratum granulosum fails to develop its keratohyalin granules, and eventually disappears half-way up the papule, as does the stratum cor-neum, so that on the summit the different layers of the epidermi cannot be differentiated.

There is neither caseation nor suppuration, but in the older part of the specimen the cells of the infiltration become swollen an disappear, and in their place there appears cicatricial connectiv tissue, which causes the papule to shrink and the whole area t assume a scar-like appearance.

Symptomatology.—The disease in the male begins on the penis, a a rule, as a papule or small nodule, which extends over skin an mucosa by peripheral growth, which is aided by the formation o new papules and nodules at the growing margin and in the health skin.

It grows into the groins, causing the hair to fall out, and betwee the scrotum and the thighs, and from thence backwards into th perineum and around the anus, into which it may pass.

When fully developed, it appears as a mass of nodules or papules, without deep ulceration as a rule, but with a thin, offensive discharge. In the older regions it shows some attempt at healing in the formation of dense scar tissue.

In the female the process begins as a papule on the labium minus, and then extends into the vagina, along the perineum, around the anus, and up the rectum, and into the groins. The growth extends into the tissue between the rectum and the vagina, and may give rise to rectovaginal fistulæ. The whole growth is also much more liable to ulcerate in the female than in the male.

The lesions may become œdematous, and present an appearance analogous to elephantiasis.

Varieties.—Daniels lays stress upon the fact that the disease varies much in different races. In negroes it is more granular, and spreads farther; in Indians it is less marked; in Fijians it is softer, and separate areas more common.

Diagnosis.—It is most likely to be confused with syphilis, lupus, and epithelioma. From syphilis it can be differentiated by the absence of the secondary eruption and the inefficacy of mercurial treatment. Lupus is very rare in such situations, and in epithelioma the lymphatic glands would be early infected. In doubtful cases microscopical examination of a piece of the diseased tissue will enable the diagnosis to be made from lupus as well as from epithelioma.

Prognosis.—The disease as a rule does not affect the general health, but is extremely chronic, lasting for years.

Treatment.—The best treatment is radiotherapy with X rays, which has been found quite successful in Madras. If these are not available, antiseptic lotions should be applied, and then portions excised, or the diseased areas may be scraped and then cauterized. Large doses of iodide of potash are said to be useful. Conyers and Daniels recommend the application of an ointment of salicylic acid gr. xxx., unguentum creosoti ℥i.

PAPILLOMA INGUINALE TROPICUM.

Synonym.—Acanthoma Inguinale (Castellani).

A peculiar papillomatous affection of the inguinal region is not rare among Tamils. Further experience will probably show that other races are also affected. Women are apparently more liable to the disease than men, inasmuch as, although the number of male patients in the Colombo Clinic and hospitals is much larger than the number of female patients, not a single case has been detected among men.

Symptomatology.—One or both inguinal regions are occupied by extremely numerous tall filiform vegetations of a pinkish or darkish colour. No ulcerative lesions are present. There is neither pain nor pruritus. The general health does not seem to be affected. The affection is very chronic, and is probably contagious, but nothing is known of the ætiology. In the cases so far observed the genital organs of the patient were normal, and there was no history of gonorrhœa or any other venereal disease.

Treatment.—The treatment is surgical—removal of the vegetation by the knife and cauterization. The patient, as a rule, however, will not consent to the operation.

SUDAN NODULES.

Thomson and Balfour have described cases of a skin affection in the Sudan characterized by the presence of pinkish nodules with a shiny smooth surface, neither scaly nor ulcerating, in which Leishmania-like bodies are found.

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CHAPTER LVIII

SKIN DISEASES (*continued*)

Craw-craw—Dermatitis nodosa rubra—Lichen convex—Symmetrical ea nodules—Keratoma plantare sulcatum—Multiple pruriginous tumours of the skin—Angiofibroma contagiosum tropicum—Juxta-articular nodules—References.

CRAW-CRAW.

Synonym.—Nodular Dermatitis (A. Plehn).

Under the term 'craw-craw' African natives denote practically any pruriginous skin disease. Our African experience has taught us that most of the so-called craw-craw cases are cases of neglected scabies or of tinea corporis. We apply the term 'craw-craw' to a dermatosis met with in Africa, in Ceylon, and in various parts of the tropics, characterized by the presence of numerous hard, *almost horny* papules, occasionally slightly exfoliating at the top, varying in size between a millet-seed and a small pea. Some of the papules may be follicular. They are not of constant shape; some may be roundish and flattened, and others acuminate. When disappearing, they may leave zones of hyperpigmentation. The eruption generally affects the legs and arms, but may spread to the whole body, excepting, as a rule, the face and scalp. Suppurative and ulcerative lesions are absent, except as secondary lesions due to scratching. The proximal lymphatic glands may be hard and enlarged. The disease, if not properly treated, may last many months, and even several years; some cases, however, become cured spontaneously.

Ætiology.—The cause of the malady is unknown. O'Neil described in his case a *Microfilaria* which Manson is inclined to believe to be probably *Microfilaria perstans*. Nielly described, under the name of 'dermatose parasitaire' or 'craw-craw,' a papulo-vesicular eruption in which he found nematode embryos in the papulo-vesicles and blood of the general circulation.

Diagnosis.—The disease with which craw-craw presents the greatest resemblance is prurigo. It is distinguished from prurigo by the eruption appearing at any time of life, and not only in childhood; by most of the papules being larger, of horny consistency, and not covered by a small bloody crust, as is often the case in prurigo; and by the fact that it may be cured spontaneously.

The disease may be distinguished from tinea corporis by the absence of any fungus, and from itch by absence of furrows, and, of course, the absence of the *Acarus*.

Treatment.—The regular application of a salicylic spirit lotion (2 per cent.), followed by β-naphthol ointment (5 to 10 per cent.) for long periods of time, often induces a marked improvement, and, in many instances, a cure. Internal treatment (arsenic, ichthyol, etc.) does not seem to influence the disease.

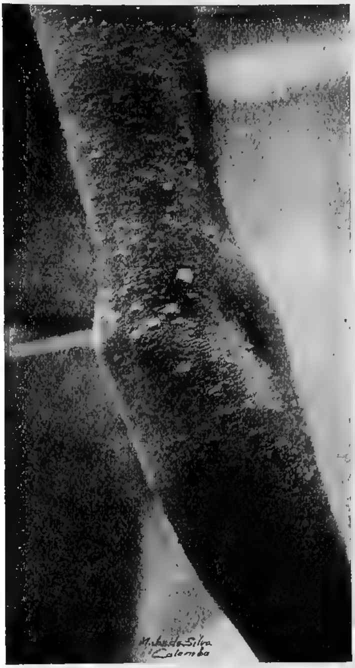

FIG. 363.—CRAW-CRAW.

DERMATITIS NODOSA RUBRA.

This condition has been described by Castellani in Ceylon. The first impression received on seeing a patient suffering from this peculiar disease is that he is suffering from smallpox in the papular stage of the eruption, but the absence of fever and the closer inspection of the eruption will exclude smallpox at once. In a well-marked case the patient presents on his face, arms, chest, back, and practically on the whole body numerous large papules and nodules. The colour of the eruptive elements is an angry red; the shape, hemispherical or roundish; the size, from a small split-pea to a large pea. The surface of the papules and nodules is smooth, does not show umbilication, nor scales; their consistency is hard; most of the papules are not follicular. There is unbearable pruritus. Several of the superficial lymphatic glands are enlarged and hard. In several cases a well-marked enlargement of the parotid gland is present. The blood shows a certain degree of eosinophilia. The course of the disease is long—six months to a year, and sometimes much longer; the nodules become gradually smaller, and may disappear completely; they leave no scar or zones of hyperpigmentation.

Diagnosis.—From a *syphilide* by the extreme pruritus and the inefficacy of mercury and potassium iodide.

From *smallpox*, the papular stage of which it closely resembles, by the absence of fever, by the chronic course, and by the fact that the papules never undergo a purulent change nor leave scars on healing.

From *lichen planus* by the papules being very large, and by their not being flattened, umbilicated, nor polyhedric.

From *pityriasis rubra pilaris* by the papules being very large, and most of them not follicular, and by the absence of plugs and scaling.*

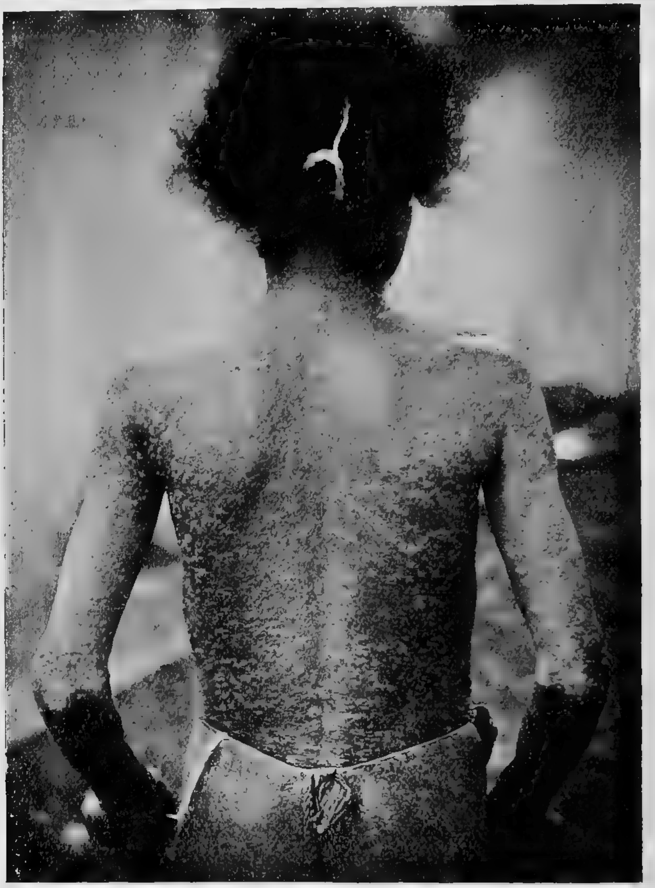

FIG. 364.—DERMATITIS NODOSA RUBRA.

Treatment.—Arsenic, potassium iodide, mercury, do not influence the disease. To allay the pruritus salicylic-alcoholic lotions (2 per cent.) and ointment may be used.

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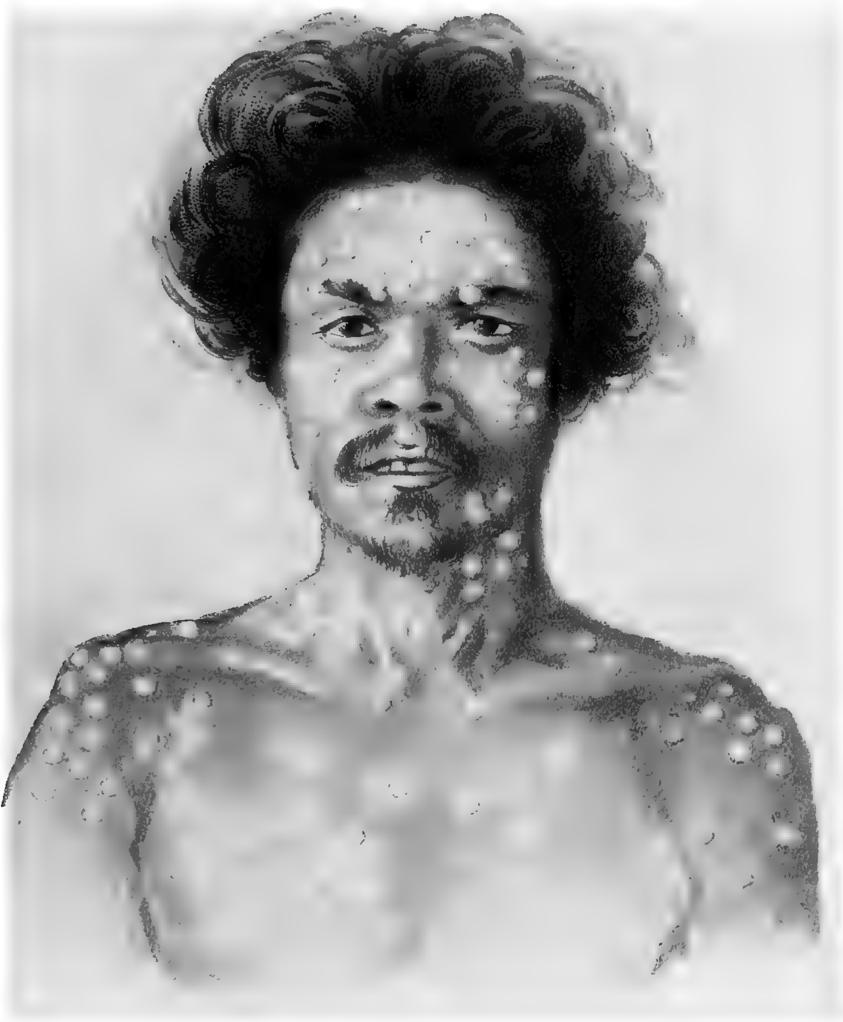
* From *acnitis* by the unbearable pruritus and by the eruption not being chiefly limited to the face, as well as by the absence of subsequent necrosis.

From *folliculitis* by the condition not being limited to the extremities, and by the absence of central crusts.

PLATE XII.



DERMATITIS NODOSA RUBRA.

IN REALITY THE PAPULES ARE OF A BRIGHTER ANGRY-RED COLOUR.

Sons, Lith. Edin *To face p*

LICHEN CONVEX.

Synonym.—Lichen Pilaris Convex (Castellani).

This affection—which has been described by Castellani—is very common in Ceylon, especially among natives. The regions of the body mostly affected are the thorax, dorsum, and shoulders. The disease is characterized by the presence of numerous firm papules, all of which are follicular. The surface of the papules is smooth; no squamæ or plugs are found; they have always a convex surface, and may be almost hemispheric, $\frac{1}{12}$ to $\frac{1}{8}$ inch in diameter. The colour of the papules has a pinkish hue in natives, and red in Europeans; they are not surrounded by any halo of inflammation, nor is there hyperpigmentation, nor do they leave pigmented areas on healing. The eruption is very pruriginous. The general health is not affected; the lymphatic glands are not enlarged; in a few cases the blood may show a slight degree of eosinophilia.

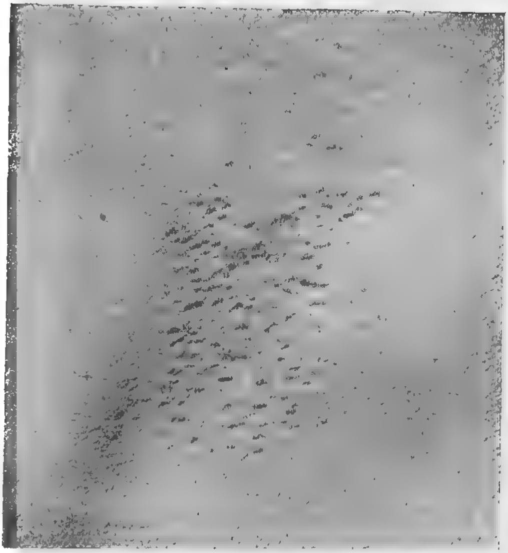


FIG. 365.—LICHEN CONVEX.

The course is long, the eruption lasting about three to nine months, and often recurring. When the eruption heals no hyperpigmentation is left.

Diagnosis.—From *pityriasis rubra pilaris* by the papules never showing plugs and by the absence of scaling; from *lichen planus* by the papules not being flattened, nor polyhedric, nor umbilicated; from *dermatitis nodosa rubra* by the papules being always follicular and not so large; from a *syphilide* by the intense pruritus; from *papular eczema* by the papules being always follicular and larger and dome-like, and by the skin not presenting a diffuse inflammation.

Prognosis.—The eruption lasts for several months, but generally heals spontaneously; recurrences are observed. The general health is not affected.

Treatment.—Potassium iodide, mercury, and arsenic have no effect. Externally, antipruriginous lotions and ointments may be used—as, for instance, salicylic-alcoholic lotion (2 per cent.), followed by naphthol ointment (2 to 5 per cent.). Change to a cool climate is very beneficial.

SYMMETRICAL EAR NODULES.

This condition has been observed by Castellani in Ceylon, but further experience will probably show that it is to be found also in other tropical countries. In the deep substance of the lobule of both ears—generally the condition is symmetrical—on palpation, a spherical nodule, hardly visible, is felt. Now and then the nodule becomes much larger, very tense, and may then present a somewhat translucid appearance; after some days it becomes smaller again, and may be barely visible. There is, as a rule, no subjective symptom during the periods of quiescence; a feeling of tension and slight pain during the periods of increase of size of the nodules.

The condition is not leprotic, there being no anæsthesia or other sign of leprosy, it may possibly be of parasitic origin, but nothing definite can be stated, as none of our patients would allow the removal of the nodule.

KERATOMA PLANTARE SULCATUM.

This disease, which is a very common affection in Ceylon among coolies and those who go barefooted, was first described by Castellani. The epidermis of the soles—especially the anterior portion—and the heels is greatly thickened, and is generally of a dark yellowish colour, and presents numerous deep segmentary furrows, straight, semicircular, or ellipsoid; these furrows appear black, but if the dirt and dust accumulated in them is removed, the fundus of these sulci will be found to be whitish or pinkish. There is no

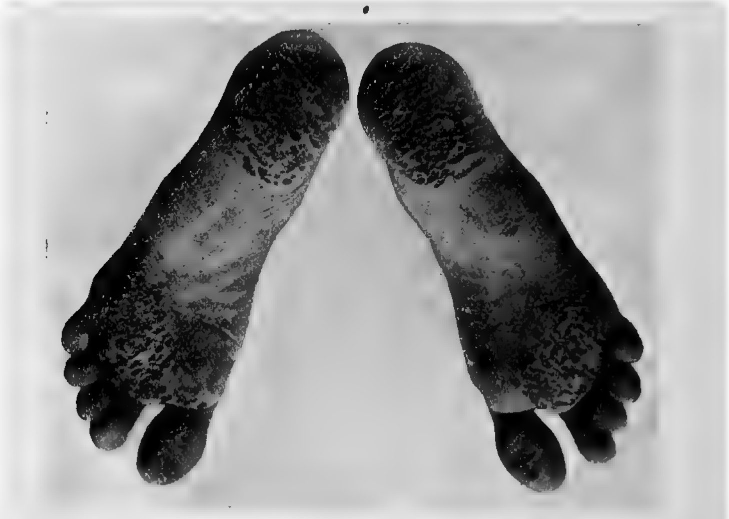


Fig. 366.—Keratoma plantare sulcatum.

sign of any local inflammation, though the patient generally complains of tenderness of the feet after much walking.

Ætiology.—The affection is much more frequent during the rainy season, and occurs generally in natives who do not wear shoes or sandals. The condition improves or disappears completely during the dry season.

Treatment.—Rest and local applications of salicylic collodion (acidi salicylici, ʒi. ; collodion, ℥i.) and salicylic ointments and plasters induce a marked improvement.

ANGIOFIBROMA CONTAGIOSUM TROPICUM.

This disease was first described by Unna and Von Bassowitz. So far, cases have been reported from the southern regions of Brazil only.

Symptomatology.—The incubation period varies from fifteen to twenty-five days. There are no prodromal symptoms. The eruption consists of vivid red papules, which soon enlarge into nodules the size of a large pea to an almond. The eruption may affect any part of the body, but more frequently the face, neck, axillæ, and genital organs. It is rarely found on the legs. It very frequently affects the various mucosæ—oral, nasal, rectal, and urethral. The nodules present a smooth surface, of a violaceous colour, and they are somewhat of soft consistency; they bleed severely after the slightest traumatism. They may disappear spontaneously without leaving any scar, or in other cases secondary infections may set in, and large ulcers develop. The eruption is not pruriginous, there is no fever, and the general health is not impaired.

Ætiology.—This is unknown, but the disease is considered to be infectious. According to Bassowitz, the infection takes place during sexual intercourse, or by the habit the people of Brazil have of taking their maté (national beverage) using the same cannule.

Histopathology.—According to Unna's investigation, the histopathology is quite different from what is observed in frambœsia and syphilis. The nodules consist of fibrous tissue, with scanty cells intersected by extremely numerous bloodvessels.

Diagnosis.—The disease must be distinguished from verruga peruviana and frambœsia. In verruga peruviana there are severe constitutional symptoms—fever, and often enlargement of the liver and spleen. In frambœsia the nodules have a moriform surface, and do not bleed so easily.

Treatment.—Mercury and potassium iodide are useless. Bassowitz recommends iron and arsenic internally, and externally the injection into the base of the nodules of a few drops of formalin, or their excision, using the galvano-cautery.

JUXTA-ARTICULAR NODULES.

This affection was first noted by MacGregor in New Guinea, and later more fully described by Steiner in natives of Java, Jeanselme in natives of Siam, where it is known as 'en no.' Cases have been observed in Madagascar by Fontoynont, and by Gros in Algeria. I the legs and arms, especially in proximity to the articulation several hard nodules are found, some of them the size of a walnu According to MacGregor, these tumours occur most frequentl about the elbows, or the parts of the body coming in contact wit the ground when the native is sleeping. These nodules may appar ently fuse together, forming hard, large tumours; at first thes are situated in the subcutaneous tissue, and the skin may be move above them; later they adhere to the skin, which generally doe not present any alteration. The course is very chronic, but occa sionally the nodules may disappear spontaneously.

Ætiology.—MacGregor, Steiner, and Jeanselme are inclined t consider these nodules of parasitic origin; while Fontoynont an Carougeau have described a penicillium as the cause.

MULTIPLE PRURIGINOUS TUMOURS OF THE SKIN.

Schaberg and Hirschler reported two cases of multiple tumours o the skin in negroes, associated with itching. The tumours wer sharply circumscribed nodules, from the size of a small pea to large hazel-nut, situated on the extremities. They were of a blackis colour—the smaller smooth, the larger covered with a horny epi dermis. These tumours showed, on histological examination dilated vessels, cellular infiltration, and the formation of new col lagenous fibres. The same eruption was previously described b Hardaway in a white woman.

MOSSY FOOT.

This affection is fairly common, according to Thomas, in the region of the Amazon.

The foot is covered with dense warty, very vascular, painful masses, as much as a half to three-quarters of an inch thick, which may spread to the leg.

The disease is very chronic, and probably of parasitic origin.

WEST INDIAN NODULES.

This affection has been described by Numa Rat in natives of the West Indies, who often confuse it with Guinea worm. The eruption may attack any part of the body, and consists of subcutaneous nodules varying from the size of a pea to that of a small nut. There is extremely severe pruritus, and the natives destroy the skin covering the nodules with caustics, and extract the nodules, which appear yellowish-white and have a cartilaginous consistency.

Histologically, according to Macleod, they consist mainly of hypertrophied connective tissue made up of thickened collagen bundles. The ætiology is unknown.

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CHAPTER LIX

SKIN DISEASES (*continued*)—DYSIDROSES AND DYSTROPHIES

Dysidroses: Prickly heat—Cheiropompholyx—Dysidrosis exfoliativa. Dystrophies: Leucoderma—Albinism—Melung—Chloasma Bronzinum—Black pigmentation of the nails—Xantoderma areatum—Tattooing—Ainhum—Symmetrical palmar erythema—References.

DYSIDROSES.

Prickly Heat.

Synonyms.—Lichen Tropicus, Sudamina Papulosa, Miliaria Rubra.

Definition.—Prickly heat is a papular or papulo-vesicular eruption, with marked pruritus and associated with profuse sweating.

Symptomatology.—This affection is extremely common in tropical countries, especially in new arrivals. The eruption consists of small pin-head papules, which may enlarge to the size of a millet-seed, and even larger. The papules are generally conical, angry red, and often occupy the orifices of the sudoriferous follicles; they are occasionally topped by a small vesicle, the contents of which may later become purulent. Besides the papules, roseola-like spots are often seen; these in some cases may coalesce and form large erythematous patches. Occasionally minute glass-like vesicles of sudamina crystallina are also present. The eruption is found on the parts of the body where the patient perspires most. It is very commonly observed round the waist, the back, chest, arms, and forehead; it may extend to the whole surface of the body, except, it is generally stated, the palms and soles. In our experience, when the eruption is general, the palms and soles also may be affected; in such situations, however, no papules are found, but only roseola-like spots. We would also call attention to another feature found in cases of acute severe general prickly heat eruption: in several such cases the oral mucosa and the fauces will appear acutely congested. The congestion subsides on the disappearance of the cutaneous lesions.

Pathology.—Pollitzer considers the disease to be due to the obstruction of the flow of sweat brought about by the cells of the epidermis swelling by imbibition from the excessive sweat.

Pearse considers it to be due to an acute distension of the sebaceous glands by their own secretion. Robinson states that the inflammation is about the sweat-pore, while, according to Török, it has nothing to do with it. In our experience, the inflammation is not always about the sweat-pore.

Durham believes prickly heat to be an infective disease caused by a minute actively mobile amœba ; his results, however, have not been confirmed.

Diagnosis.—This is generally easy ; from eczema it is distinguished by the greatly increased flow of perspiration, and by the absence of any moist lesions during the whole course of the malady. Our experience is, however, that in some rare cases true eczema—especially of the papular type—develops on prickly heat lesions. In cases of generalized prickly heat, with roseola-like spots on the palms and soles, acute patchy congestion in the oral mucosa and pharynx, a syphilide must be excluded, for several of our patients believed themselves to be affected with syphilis ; but the extreme pruritus is generally sufficient to exclude it.

Prognosis.—As a rule, the prognosis is good, the eruption disappearing quickly under proper treatment. In some few cases, however, no treatment is of any avail, and the patient must be sent up to the hills ; in others, crops of boils develop.

Treatment.—The patient must be kept cool ; too warm clothing should be avoided ; he should not take much to drink, and should abstain from drinking hot tea. The treatment which in our experience has answered best is the free use, several times daily, of a salicylic-alcoholic lotion (ac. salicyl. ʒi., spir. rect. ℥viii.), followed by the general application of a salicylic or boracic powder, such as ac. salicyl. gr. x., talci ℥i. ; ac. borici ʒi., talci ven. ℥i. It is better, as a rule, to avoid greasy preparations.

After the eruption is cured the patient should be directed to use some Condy's fluid, cyllin, or other disinfectant in the bath, and afterwards to apply one of the powders mentioned above.

Cheiropompholyx.

Synonyms.—Dysidrosis, Pompholyx.

This affection is seen in the tropics, and is also met with in temperate zones during the hot season. To Tilbury Fox and J. Hutchinson belongs the merit of having separated this affection from eczema.

Ætiology and Histopathology.—Tilbury Fox believed the disease to be due to accumulation of sweat induced by the blocking of the pores of the sudoriparous glands. The more recent researches of Unna, Norman Walker, Williams, and others show that the lesions are of an inflammatory character ; the vesicles are found in the prickly layer, and often press to one side the sweat-channel.

Unna has described a bacillus as the cause of the disease , his results have not been confirmed. Some authorities consider the disease to be of neurotic origin.

Symptomatology.—The eruption is found in individuals who suffer from hyperidrosis. It is characterized by the presence of deeply-seated translucent or opalescent, sago-like vesicles between the fingers and toes; the vesicles are not, as a rule, surrounded by an inflammatory halo; they very rarely coalesce, and usually do not break, but dry up gradually, being thrown off with the exfoliating epidermis. The vesicles in many cases are few in number; in others they may be numerous, and the eruption may extend to the palms, backs of the hands, and occasionally the arms. There is unbearable pruritus, and in some cases, owing to the scratching, an eczematous dermatitis may develop, especially between the toes.

Diagnosis.—Some authorities still maintain that cheiropompholyx is merely eczema. In our experience, the disease must be separated from eczema, the principal characters of differentiation being the deep situation of the vesicles, the fact that they very rarely rupture, and that, as a rule, they are not surrounded by an inflammatory zone; moreover, the parts affected are generally bathed in sweat.

Prognosis.—The disease is not a serious one, and, under proper treatment, the eruption heals; but the tendency to recur is great.

Treatment.—When the vesicles are few in number, pricking them with a sterile needle, washing them with a perchloride lotion (1 in 2,000), followed by the application of a 1 to 2 per cent. naphthol ointment, gives much relief. When the vesicles are numerous, and the eruption has spread to the backs of the hands and arms, calamine lotion, to which a little menthol and alcohol has been added, answers well.

Dysidrosis Exfoliativa.

This affection is closely related to cheiropompholyx. The affected parts—generally the palms of the hands—are bathed in continuous perspiration, and large flakes of epidermis exfoliate. In most cases no cheiropompholyx-like vesicles are found; in fact, no vesicles of any type can be detected. The affection becomes cured spontaneously on the patient going to the hills or during the cold season, but it is apt to recur.

Bathing the affected parts with a resorcin lotion (½ per cent.) at first, and later, when the desquamation has ceased, the application of calamine lotion, is useful.*

DYSTROPHIES.

Leucoderma.

Synonyms.—Leucopathia, Vitiligo, Acquired Leucopathia, Acquired Leukasmus, Acquired Achromia, Acquired Piebald Skin.

Leucoderma is much more common in tropical countries than in temperate zones. The natives of Ceylon and India have a dread of developing leucoderma, and look upon it as a loathsome disease.

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* Schornberg has applied the term '*sweat desquamation*' to the minute whitish scales, often arranged in rings, and found on the palms of persons who perspire profusely.

Ætiology and Pathology.—The ætiology is unknown. It is generally considered to be a trophoneurosis. Occasionally there is evidence of hereditary influences, several members of the same family being affected. The malady may start after an injury, after a burn, after too strong a caustication. In fact, the application of strong remedies should be used with care in natives. We have seen leucoderma patches appearing after the application of pure formalin. Patches of leucoderma may develop also in chronic epiphytic skin diseases, the fungi apparently having a deeply disturbing effect on the pigment formation.

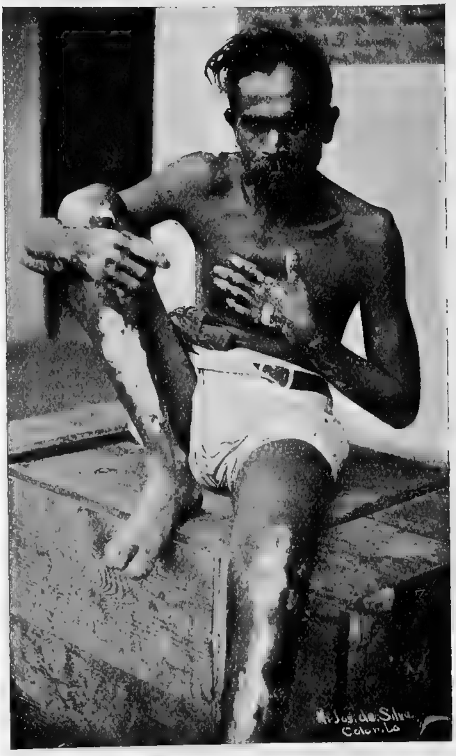


FIG. 367.—LEUCODERMA IN A SINHALESE.

Symptomatology.—Leucoderma is characterized by the presence of non-pigmented areas, white, ivory-like, or pinkish. The patches are roundish or oval, with a smooth surface; they slowly enlarge and coalesce, giving rise to large, irregularly outlined areas. Occasionally almost the whole body becomes affected; more often it is the face and hands which are affected, and there may be a certain symmetry. The initial patches are generally surrounded by a zone of hyperpigmentation. Occasionally within the white areas small dot-like zones of pigmentation are left. The hairs of the affected parts often become white, but sometimes remain of normal colour. The white patches do not show any marked change in sensation; there is never anæsthesia; in many cases there is hyperæsthesia to heat and light stimulation. The texture of the skin remains normal; occasionally slight atrophic processes may be noted. It is usually stated that the general health is not impaired. In our experience, however, when the patches are large and situated on uncovered parts of the body, especially the face, symptoms of severe asthenia have been noticed. Moreover, the patients complain that they cannot do any work in the sun, as they experience a burning sensation in the white patches, and they suffer from giddiness.

Diagnosis.—The diagnosis is generally easy. The patches, in contrast to leprosy, do not show anæsthesia; from *morphœa* it is distinguished by the absence of any abnormality in the texture of the skin from tinea flava, tinea alba, and pinta, by the absence of any fungus

Prognosis.—The disease is generally incurable. When large patches are present the patient complains often of asthenia, and may become unfit for work, especially work in the open air and sun.

Treatment.—The disease is generally incurable, but the spreading of the patches may be prevented, and occasionally a slight improvement may be brought about, in our experience, by an energetic arsenical treatment. We generally give arsenious acid in a pill (gr. $\frac{1}{50}$) three to six times a day, or atoxyl injections (5 grains every other day). Gillmore has tried soamin with fairly good results. We have seen no benefit from the administration of suprarenal extract, as recommended by several authors. The white colour may be partially hidden by applying a lotion of nitrate of silver or potassium permanganate, or by tattooing.

Heidingsfelt has devised an instrument consisting of a group of ten needles, which are put in movement by electrical power. In this way tattooing may be performed much more rapidly than by hand.

Sommer claims to have cured several cases of leucoderma by injections of adrenalin.

Albinism.

Synonyms.—Congenital Leucoderma, Congenital Leukopathia, Congenital Achromia, Congenital Leukasmus.

The affection is found in the tropics more frequently than in temperate zones. It is characterized by congenital absence of pigment in the skin, hair, iris, and choroid. There are cases, however, of partial albinism in which only the skin is affected. The skin has a milky-white or pinkish appearance; the iris is rose-coloured, and the pupil red. There is intolerance to light; hence the pupils will be generally found to be contracted, and the patient, to avoid the strong light stimulus, may go about with the head downwards. Nystagmus is observed in several cases. The hair is generally white or yellowish-white, fine and silky. We have seen albinos with red hair. Albinos are generally poorly built, weak and feeble individuals.

Ætiology and Pathology.—The ætiology is unknown. The affection is more often observed among coloured races than in the white races. It shows a certain family tendency. It is said that cases occur more frequently in the offsprings of consanguineous marriages. The histological examination of the skin shows absence of pigment as the only abnormality.

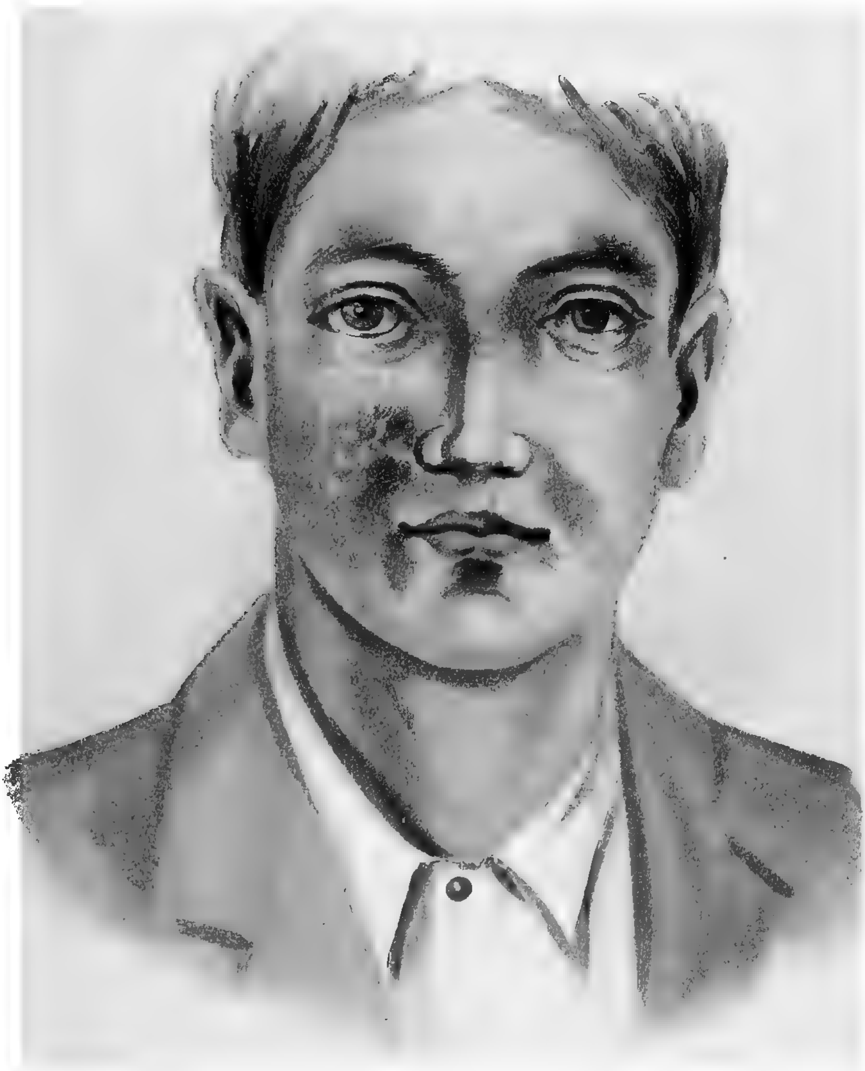
Treatment.—The affection is incurable.

Melung.

Synonym.—Beta.

This affection was first described by Ziemann, and is fairly common among West African negroes. The affection is always

PLATE XIII.



CHLOASMA BRONZINUM.

n & Sons, Lith, Edin

To face p

symmetric, and attacks only the palms or the soles, or both palms and soles. Small areas of the skin undergo a slow process of depigmentation, becoming whitish or yellowish; there is no alteration of sensibility. The depigmented areas, which are generally of various shape, are intermixed with patches of normally pigmented skin, so that the palms and soles present a marmoriform appearance.

The disease is chronic and incurable. It often develops in childhood, and several members of the same family may be affected.

Chloasma Bronzinum.

This somewhat rare affection, described by Castellani, is met with among natives as well as Europeans in India, Ceylon, the Malay States, and other tropical countries.

Ætiology.—This is unknown, but a life in the open air with daily long exposure to a tropical sun is apparently an important predisposing cause. All our patients were European planters or native overseers of coolies.

Symptoms.—Part of the face or the neck, or occasionally the whole face, neck, and chest, presents a peculiar pigmentation, resembling a black bronzine mask; the pigmented areas slowly but steadily increase. The disease is very chronic and incurable. The general health is not impaired. The examination of the various organs is negative. The blood and urine are normal.

Diagnosis.—This is easy, even in very dark-skinned natives, the affected parts being completely black, and having a characteristic bronzine hue.

From ordinary chloasma, which is not rare—especially among women—the affection is easily distinguished by the bronzine tint. The absence of asthenia, loss of flesh, and diarrhœa, will suffice to distinguish chloasma bronzium from Addison's disease; the history and the examination of the blood will differentiate it from malarial pseudo-Addison's disease; the examination of the urine will distinguish it from diabetes bronzinum. Argyria will be excluded by the history and by the fact that in chloasma bronzinum the mucosæ are not affected.

Prognosis and Treatment.—The disease is incurable.

Black Pigmentation of Nails.

Castellani has described in two European ladies a peculiar condition of the nails characterized by a band of black pigmentation along the free border of the nail. On superficial examination, it has the same appearance as though some dirt had accumulated beneath the free border of the nail, but on scraping, this pigmentation does not disappear, and this shows that the condition is due to some pigmentation in the substance of the nail. The sufferers were in general good health, not using any internal or external medicine which could account for the pigmentation, and the nails, apart from this line of pigmentation, appeared perfectly normal. Recently we have come across a case in a European gentleman.

The condition slowly disappears spontaneously.

Xanthoderma Areatum.

This affection, which has been described by Castellani, is not infrequently met with among Europeans ; it generally affects the lower parts of the legs ; it starts very insidiously, with a yellowish or reddish-yellow spot, which is not elevated ; the surface is smooth, not furfuraceous ; there is no infiltration, and, apart from the colour, the affected skin is normal. There is no pruritus and no pain. The yellow spot slowly increases, and one or more other spots may appear near the first one or at a distance. Some of the spots may coalesce together, forming a large yellow-red patch of irregular or various outline. The larger patches also, apart from the colour, are normal, being of normal consistency and elasticity. The disease is very chronic. The general health is not impaired ; the lymphatic glands are not enlarged, and the blood does not show any abnormality ; urine normal. In all our cases syphilis could be excluded ; in none was there any history of traumatism.

Diagnosis.—From chloasma, xanthoma areatum is readily differentiated by the lighter yellow or yellowish-red, and by the different situation. The affection can be easily distinguished from xanthoma, as the texture of the skin is normal, and the patches are not elevated. In pseudo-xanthoma elasticum of Balzer there is an eruption consisting of mesh-like patches of buff-coloured infiltration, lumpy in some places, in others linear.

Treatment.—This is difficult ; in some cases an energetic exfoliating treatment by resorcin pastes (resorcin, ʒii. ; ac. salic., gr. xx. ; Lassar's paste, ℥i.) improves the condition after the inflammation induced by the paste subsides.

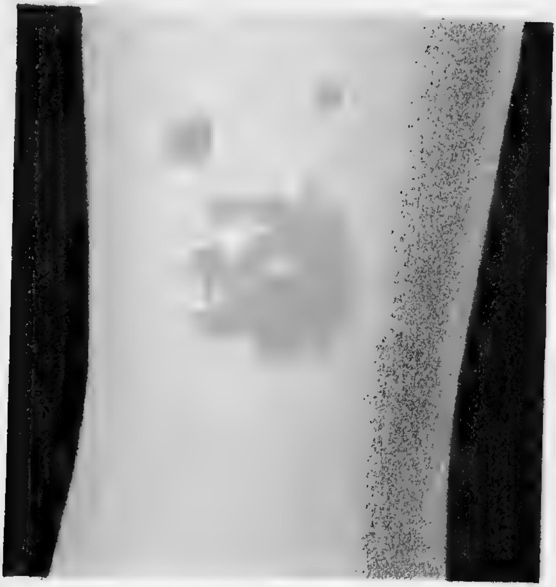
Tattooing.

Nomenclature.—The word 'tattoo' is derived from 'tattow,' used by Cook and Banks in their journals in 1789. Tattow was derived from 'tau' or 'tatu,' a word which meant 'marking.' The Maori word is 'amoca' or 'moko,' which, however, refers to the furrowing of the skin—a more formidable operation than tattooing.

Definition.—Tattooing is the formation of more or less indelible marks in the skin by means of rubbing pigments or irritating substances into slight wounds made for the purpose.

General Account.—It appears to us that tattooing was originally preceded by face and body painting, which in the form of 'war paint' is well known to have been used in many savage tribes when about to enter into combat with their enemies. At first this

PLATE XIV.



XANTHODERMA AREATUM.

ton & Sons, Lith Edin

To face

painting was very simple, and consisted in merely smearing the face with some form of pigment, but eventually in certain peoples it became more and more elaborate. Painting, however, is only a temporary method of adornment, and many peoples have adopted in its place the permanent tattooing. The essential reason for tattooing is the ornamentation of the person, but taking its origin in the custom of painting the face before going to war, it is generally more elaborate in men than in women.

In Africa the marks have a most varied significance. Thus, according to Hobley, the Ja-Luo girls are tattooed because it is thought that unless this is done a woman will not bear children. Among the Ketosh, the warrior, after killing an enemy in warfare, has two rows of marks tattooed on his right chest and shoulder, to prevent the spirit of his dead enemy bewitching him.

In its simplest form it is seen in West Africa, where short straight skin-cuts are made by means of a sharp piece of iron, after which some pigment or irritating substance is rubbed into the wound, the idea being to produce a keloid. If this fails, another cut is made into the same place, and more pigment is rubbed in, until the desired result is attained. These cuts, and hence the subsequent keloids, are arranged in some primitive form of pattern. More elaborate patterns, however, may be met with, being generally in the forms of curved lines or scrolls of keloids.

In the Naga Hills of Assam the lines of the tattoo follow the contours of the face.

The most elaborate designs are found among the Maoris of New Zealand and the natives of the Pacific Islands. The Polynesians use lines and curves, but not spirals, the highest art being found among the Marquesans. The Maoris are, however, not content with mere tattooing, in which pigment is rubbed into slight cuts, for in their ‘ moko ’ they make deep furrows, which remain more or less permanently during life. According to Ling Roth, the Maoris use seven patterns : the first, *the linear*, composed of lines of dots or strokes ; the second is *the mat* or *plait-work pattern*, composed of parallel lines, in groups of three, arranged more or less alternately. The third is *the ladder pattern*, in which the lines are arranged in horizontal groups separated by clear spaces. The fourth is *the chevron pattern*, being composed of coils with long tails or handles, the interspaces between which are filled in by slanting lines. The fifth pattern is *the circinate coil ;* the sixth, *the anchor ;* and the seventh, *the trilateral scroll.* This last pattern is said to imitate a flower—*Clianthus puniceus.* According to the same author, the Papuans are much addicted to the use of the spiral in tattooing. The Polynesians use simple pricking instruments, while the Maoris, in order to produce the deep furrows, use special instruments, shaped somewhat like a miniature garden-hoe, the cutting edge of which is toothed. These instruments were at first made of bone or hard wood, but later iron was introduced. They are made to cut the skin by means of blows from a hammer or a stick. As a result of the wound, the blood flows freely, and is wiped away by the hand or a piece of stick, after which the pigment is rubbed into the wound. The nature of this pigment appears to vary, and may consist of charcoal, obtained by burning various animal or vegetal substances. The hair of the beard has to be pulled out by the roots, as it would spoil the effect of the tattoo or moko.

The pain of the operation of moko is naturally very great, especially when performed on the lips, and hence but little tattooing can be done at a time, and it takes years for an extensive moko to be produced. Inflammation often sets in, and it may be weeks before the wounds heal. The Maoris perform post-mortem tattooing and moko at times, but this is to be distinguished from tattooing made during life by the appearance of the cuts and the absence of subcutaneous colour.

In modern times the art of tattooing has been much developed by the Japanese, into whose country it was introduced about 300 years ago. The Japanese artists, by using special instruments composed of fine and coarse needles, and by rubbing in various coloured pigments, produce the well-known designs so commonly seen on the arms and bodies of Europeans and Asiatics.

Varieties.—The different varieties of tattooing described above may be classified as follows :

I. Simple tattooing—
   (*a*) Without furrows—tattooing of Japan and elsewhere.
   (*b*) With furrows—moko of New Zealand.
II. Keloid tattooing—tattooing of Africa.

Disease.—Tattooing is not free from danger, for blood-poisoning, and even death, may result, while syphilis and tuberculosis of the skin may be acquired through the wounds.

Treatment.—When the marks are small, excision may be resorted to, but in general any attempt at removal fails. When the tattooing is performed with gunpowder, it is said that the marks can be removed by painting with di-iodide of ammonium in solution, and afterwards with dilute hydrochloric acid.

Ainhum.

Synonyms.—Quigila (Brazil), Sukha Pakla (India), Faddidite (Madagascar).

'Anyum,' or 'ainḥum,' is derived from a Yoruba word meaning to saw or to cut.

Definition.—Ainhum is a chronic disease of the fifth, and more rarely of the fourth and other toes which occurs in native races, and is characterized by the formation of a furrow at the digito-plantar fold, which deepens and extends until it encircles the toe, which is finally severed from the foot.

History.—The disease appears to have been first mentioned by

Clarke in 1860, who, in his description of the Gold Coast, drew attention to a dry gangrene of the little toe found in negroes in that region. In 1867 Da Silva Lima described fifty cases of the disease in Brazil, and introduced the term 'ainhum'; and in the same year Collas wrote an account of the disease. Da Silva Lima ventured no explanation of the disease. In 1873 Crombie described the disease as occurring in India; in 1876 Pirovano found it in Buenos Ayres; and in 1877 Corre mentions it in Réunion.

It is reported in the West Indies by Potoppidian in 1879; in North Carolina by Hornaday and Pitman in 1881; in Nossi-Bé by Deblenne in 1883; in Western Virginia by Duhring in 1884. This last observer, along with Wile, studied the disease microscopically, considering the essential pathological feature to be an inflammatory œdema of the hypodermis. In 1886 Eyles wrote an excellent account of the pathological histology of the disease as seen in the Gold Coast, concluding that irritation caused an internal proliferation of the epithelium, which, extending into the cutis, damaged the vasomotor nerves, leading to a spasm of the vessels, endarteritis obliterans, fibrosis of the cutis, and rarefying osteitis, whereby the digit is separated from the foot. After this date there are a number of papers, among which may be specially mentioned those by Moreira, Dalgetty, and Maxwell in 1900, Muir in 1903, and Ashley-Emile in 1905.

Climatology.—The disease is known in South America, especially in Brazil and the Argentina, and also in British Guiana; in North America, especially in the Southern United States, but also in the Northern and in Canada. It also occurs in the West Indies. In Africa it is especially well known on the West Coast, and particularly in the Gold Coast, but it also occurs in Egypt, East Africa, Madagascar, and the Transvaal. In Asia it is known in India, China (?), and Ceylon. It also occurs in Polynesia.

Ætiology.—The causation of the disease is by no means well known, but a prominent factor is the racial, for it practically only occurs among native races, and in all probability the reports of its occurrence in Europeans are erroneous. The theories suggesting that the disease is due to leprosy, wearing rings or other tight bands, self-mutilation, may be dismissed at once, as there is nothing to support them.

We are of opinion that Eyles and Moreira are correct in their view that the reason why the native races are attacked is because they walk barefoot, and that the true causation is probably irritation or injury to the skin of the little toe, which is more likely to occur in negroes, who often are flat-footed. It is more common in males than in females, in adults than in children, and, though it can apparently be found at any age, is most common between thirty to thirty-five years.

Pathology.—The constant irritation causes the epithelium to proliferate internally and depress the skin, and cause the fibrous tissue of the cutis to proliferate. There is also an endarteritis, by which the blood-supply is gradually cut off the distal portion of the toe, which therefore becomes œdematous and fatty, while the bone undergoes rarefying osteitis, so that the digit is gradually separated from the foot, a process which takes place through the bone of a phalanx. The morbid anatomy at the line of the furrow shows proliferation of the epidermis, which projects downwards into the cutis, in which the connective tissue is increased in quantity. The vessels show endarteritis and periarteritis ; the sweat-glands show proliferation and fatty degeneration of the cells. The bone is in a condition of rarefying osteitis.

Distally to the furrow the joints are effaced ; the tissues show fatty degeneration and œdematous infiltration. No organisms can be found.

Symptomatology.—The disease is purely local, and is not, in our experience, attended by any general symptoms. It begins, as a rule, as a furrow on the inner side of the digito-plantar furrow, which slowly deepens and extends laterally and dorsally until the two wings meet on the dorsum of the toe. While this is proceeding the distal portion of the toe becomes swollen, and may appear as a small globule surrounded posteriorly by a deep groove, by which it is separated from the rest of the foot. Often an ulcer forms on the inner side of the groove, and may cause much pain.

Left to itself, the disease will last from two to ten years, though cases have been reported of fifteen to fifty years' duration ; but eventually the toe drops off, or is knocked off, or is removed. The process may, however, begin again in the stump.

Usually the fifth toe is affected, but in about 10 per cent. of cases the fourth toe may be affected, and much more rarely the second or the hallux. There are reports of the affection occurring also in the fingers.

Diagnosis.—The diagnosis affords no difficulty.

Prognosis.—There is no danger to life in the disease.

Treatment.—The disease is best treated by making a longitudinal cut into the groove, when its progress may be stopped.

Prophylaxis.—The essentials of the prophylaxis are cleanliness, and the wearing of stockings and boots to protect the foot from injury.

Symmetrical Palmar Erythema.

Chalmers, in 1899, drew attention to a symmetrical non-pruriginous palmar erythema found in Europeans on the Gold Coast, and extending along the ulnar side of the palms of the hands. The affection was very persistent.

Mongolian Spots.

Peculiar mulberry or bluish coloured, smooth, non-elevated, roundish, or variously outlined spots are frequently found on the skin of the lower spine and sacral regions of Japanese, Chinese, and also occasionally in white and coloured races. The colour of the spots does not disappear on pressure. Probably they are congenital.

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CHAPTER LX

SKIN DISEASES (*concluded*)—'COSMOPOLITAN SKIN DISEASES'

General Remarks—Pyogenic infections—The erythemata—The exanthemata—Urticaria—Dermatitis venenata—Parasitic diseases—Bullous eruptions—Herpes—Eczema, psoriasis, seborrhœa, and dermatitis exfoliativa—Acne—Hyperidrosis and bromidrosis—Lichen—Tumours—Tuberculosis—Syphilis—Ichthyosis—Kaposi's disease—Chloasma—Diseases of the hair and nails—Some cosmopolitan diseases of mucous membranes.

GENERAL REMARKS.

In our experience, all the skin diseases met with in temperate zones are also found in the tropics, except those due to intense cold, such as erythema pernio and frost-bite, and even these may also be found in the high mountainous regions of the tropics.

The diagnosis of some of the cosmopolitan dermatoses may, owing to the colour of the skin of native races, be very difficult to the medical man newly arrived in the tropics. This is probably the cause of some of the statements that such common diseases as lichen planus and psoriasis are absent. There is no doubt, however, that some dermatoses which are frequently met with in temperate zones are less common in the tropics.

It is stated by some authorities that coloured races are, on the whole, less liable to skin diseases than the white races, but the reverse is more in accordance with our experience.

A few remarks as to the normal skin of native races may be useful before proceeding to review the various cosmopolitan diseases. In the African races and American negroes who descend from African negro stock (Guinea negroes, Yoloffs, Caffres) the whole skin, especially the derma, is thicker than in the white races. In Indian races the skin is about the same thickness as in Europeans, except in the Tamils, whose skin is somewhat thicker. As noted by Howard Fox, the glandular system—sweat glands and sebaceous glands—is much more highly developed in the native races, especially the African negroes. The sebaceous secretion is the cause of their peculiar odour and the shining appearance of the skin, and the large secretion of sweat, which, owing to the high temperature, quickly evaporates, is the probable cause of the skin feeling cooler when touched. In native races the hairy system is less developed, except in the scalp; in the African races the hair of the head is generally curly or woolly; in Indian races it is usually smooth. The slight development of lanugo hair is the cause, as noted by Fox, of the peculiar velvety feeling of the negro skin.

The most important characteristic of the skin of tropical native races is the dark pigmentation. It is said that this pigmentation is not present at birth, but develops within a few hours to several days after birth. In our experience, it cannot be doubted that at the time of birth in many cases the babies present a much lighter colour than the adult people. The skin, however, is not whitish, but of a muddy brownish colour, and darkens greatly within a few days—in some cases is quite dark also at the time of birth. It is said that the pigmentation increases till puberty, and then, after remaining stationary during adult life, slowly decreases during old age. The maximum pigmentation is found on the loins, posterior portion of the trunk, shoulders, buttocks, and thighs; the least pigmentation is found on the prepuce, vulva, palms, and soles. In some races the oral mucosa is not pigmented; in others there is a patchy dark pigmentation which extends often to the tongue. The dark patches on the tongue have been considered by several writers to be a pathological condition, and a sign of agchylostomiasis. We have observed such patches, however, in numbers of normal natives. The hair is said to become white at a later date among negro races than in Europeans; we have not noted any distinct difference, either among them or the natives of Asia.

It is said by some writers that native races, and especially the negro African races, are less susceptible to pain than the white man. In our experience there is hardly any difference in the ordinary dolorific sensibility, but the thermic sensibility is probably less.

PYOGENIC INFECTIONS.

These are very common in tropical countries. **Impetigo** and **Ecthyma** lesions are frequently met with. The symptoms and course are identical with what one finds in temperate zones, and the treatment is the same—removal of the crusts, disinfection with a lotion, such as a perchloride of mercury (1 in 2,000), and dressing with a white precipitate ointment (1 per cent.).*

Boils.—This is a common affection in the tropics, very stubborn, and difficult to cure. The quickest and most reliable method of administration of yeast preparations internally will be found to be useful in some cases—*e.g.*, ceridin pills. Occasionally a small boil may be aborted by applying a droplet of pure carbolic acid by means of a pointed pencil of wood drilled into the centre of the papule. For old indurated boils the continuous application of a carbolic lotion (2 to 5 per cent.) on lint occasionally causes them to become absorbed.

As a preventive, a salicylic-alcoholic lotion (1 to 2 per cent.) used after the daily bath is advantageous.

Sycosis Coccogenica.—This is fairly common in both Europeans and natives. In the negroes Fox has often observed the formation of tiny cheloidal tumours after this affection. Depilation—by X rays when possible—is the best method of treatment. We have observed a case of *Dermatitis papillaris capilliti* (Kaposi).

Erysipelas.—Ordinary erysipelas due to streptococci, and to be distinguished from the filarial erysipelatoid attacks preceding the development of elephantiasis, is not rare. Ichthyol ointment or lotion (10 per cent.) answers well.

THE ERYTHEMATA.

Erythema solare is common in Europeans freshly arrived, and in those who live an open-air life, such as planters. It is followed by pigmentation (sunburn; see Chapter III.). The application of calamine lotion, followed by the use of boric vaseline or rose-ointment, is beneficial.

Erythema intertrigo is very frequently observed in corpulent persons. Washing the parts with a potassium permanganate solution (1 in 5,000), followed by application of boric-talc or salicylic-talc powder (acid. boric., ʒi., talci, ℥i.; ac. salicyl., gr. x., talci, ℥i.), is useful. Persons suffering from intertrigo are very liable to become infected with tinea cruris.

Erythema nodosum—**Erythema multiforme.**—These affections are occasionally met with, but much more rarely than in temperate zones.

Erythema annulatum and **Erythema gyratum,** in persons suffering from fever, and coming from tropical Africa, should always arouse the suspicion of trypanosomiasis.

Diffuse **Erythema scarlatiniforme** and **Erythema morbilliforme** may be seen in some malarial patients. It may occasionally be caused by quinine, but in most cases is of malarial origin. The diagnosis of erythemata in dark natives is difficult. The medical man of long experience, however, will be able to detect a peculiar shiny aspect of the skin, with a distant pinkish tinge.

Purpura.—Schönlein's purpura, Henoch's purpura, and Werlhof's purpura are not common in the tropics, though we have seen cases. A symptomatic purpura eruption is occasionally seen in the last stage of kala-azar.

THE EXANTHEMATA.

Small-pox, chicken-pox, and measles are very common in tropics, though scarlet fever is but rarely met with.

Small-pox is very common, and often spreads in exten epidemics, and may present the confluent type and the hæn rhagic type, which is rare in Europe. In colonies under Europ rule vaccination is extensively practised. The vaccine does retain its immunizing properties for more than a few weeks in tropics, and hence it is advisable for each colony to be provided a central vaccine depot where the lymph can be prepared u careful supervision. Owing to the habits of the lower classes to many of the vaccinators being non-medical men, serious infect with other diseases may occur.

Measles may be difficult to recognize, as the eruption in d skinned races is better felt than seen, but the coryza and o symptoms are generally sufficient to enable a correct diagnosi be made.

URTICARIA—LICHEN URTICATUS—PRURIGO.

Urticarial eruptions are as frequent in the tropics as in tempe zones, though to the newcomer the diagnosis of urticaria in d skinned natives is far from easy. Of **lichen urticatus** we have several cases among European and half-caste children, and of **urtic pigmentosa** we have seen one case—a European child. We observed true **prurigo** of Hebra in two native girls.

DERMATITIS VENENATA.

Several tropical plants and grasses produce substances hi irritating to the skin, but the subject has already been treate Chapter VI. (p. 97). The dermatitis so caused may be urtica erythematous, eczematous-like, or bullous, and may extend to portions of the body. The forms of dermatitis venenata du animal agents, such as ants, bugs, caterpillars, etc., have already mentioned in Chapter VIII. In Algeria and Ital urticarial eruption is caused by *Pediculoides ventricosus* New 1850, which lives in diseased cereals.

PARASITIC DISEASES.

Trichophytoses.—In tropical countries, in addition to the tri phytoses peculiar to the tropical climate, several other form trichophytic affections occur which are clinically identical those met with in temperate zones, such as tinea circinata, capitis, tinea barbæ. The fungi are, however, in most

The fungi found in the tropics are generally large-spored ones. *Microsporon audouini* has never been found by us, but a few cases of tinea capitis due to it have been described by Jeanselme and others. *Favus* is rare in tropical Africa and Asia, but common in China.

Pityriasis versicolor.—The pityriasis versicolor of temperate zones is found also in the tropics. It is to be noted, however, that several writers on tropical medicine confuse pityriasis versicolor with another dermatomycosis which is extremely common—tinea flava.

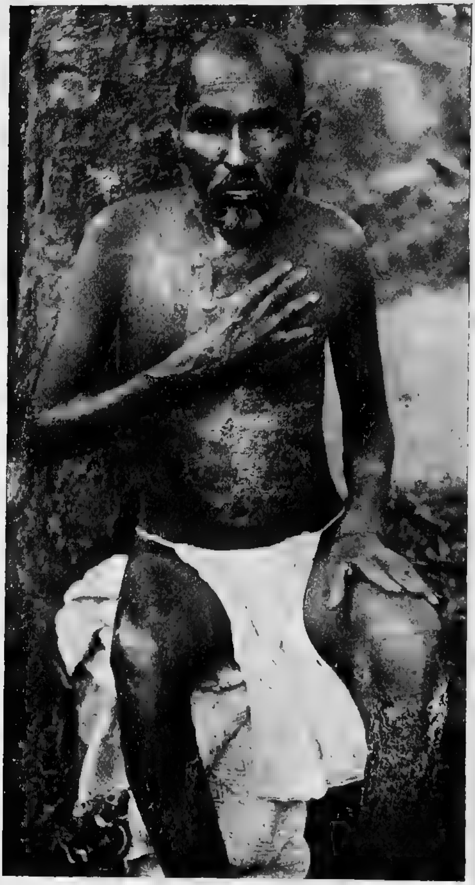

FIG. 368.—SEPTIC PEMPHIGUS.

Pediculosis and Scabies.—*Pediculosis capitis* is extremely common, although natives generally take great care to keep their hair in order by regularly combing, washing, and oiling. According to Fox, Carmichael, and Pendergast, pediculosis capitis in the Southern States of North America is much less frequent in the negroes than in the whites, as, according to them, the negroes take greater pains in the care of the scalp than the lower-class whites. *Pediculosis corporis* and *pediculosis pubis* are as frequent in the tropics as in temperate zones, and so is scabies. A disease closely resembling scabies, but due to a somewhat different *Acarus*, is common in Ceylon.

BULLOUS ERUPTIONS.

Epidermolysis bullosa is occasionally observed.

Pemphigus vulgaris and **Septic pemphigus** cases are not rare in the tropics. In the cases of septic pemphigus we have always found virulent streptococci. The eruption is similar to what one sees in temperate zones. We have seen a case of **Pemphigus vegetans,** and we have seen a typical case of **Pemphigus foliacæus,**

contracted in Ceylon, and another in Indo-China. **Dermatitis herpetiformis** is not rare.

Of **Hydroa vacciniformis** we have seen two cases in European children.

HERPES.

Herpes facialis febrilis is common during attacks of malarial fever and other fevers, but very rare, as is well known, in enteric.

We have seen in European children a similar condition to what some French writers call *fièvre herpétique*. The condition, as seen by us, is characterized by a sharp attack of fever lasting about twenty-four hours, and at the same time by the appearance of a few herpetic vesicles—in our cases on the thighs and buttocks.

Herpes progenitalis is very common, especially in Europeans.

Herpes zoster (zona, shingles) is frequently met with in Europeans and natives.

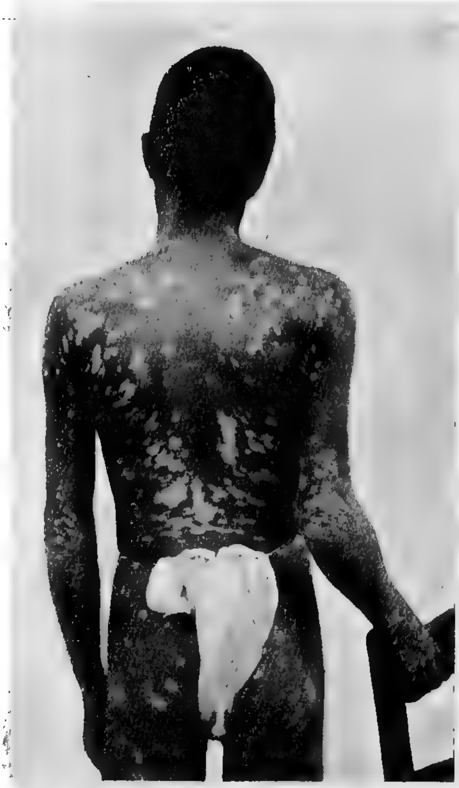

FIG. 369.—PSORIASIS IN A SINHALESE.

ECZEMA — ACRODERMATITIS PERSTANS —PSORIASIS—PARAPSORIASIS — SEBORRHŒA—DERMATITIS EXFOLIATIVA.

Eczema is extremely common, and all varieties of it are found in the tropics, as in temperate zones, both in natives and Europeans. Some cases of diffuse eczema will improve only on the patient going to a cooler climate. Wilson's eczema verrucosum, characterized by great dryness and hardness and warty appearance of the affected parts, is frequently met with among natives, in whom it attacks the toes.

Acrodermatitis perstans.—We have seen two cases of a very obstinate chronic dermatitis on the extremities of Sinhalese, apparently identical with acrodermatitis perstans of Hallepeau.

Psoriasis is considered by most writers to be extremely rare or absent in native races in the tropics. Rutz states that he never saw a single case of psoriasis in a negro during his many years of practice in Martinique. Howard Fox, senior, thinks that possibly the savages of Africa are free from psoriasis on account of exposure of the skin to sunlight, and that the negroes of North America have inherited this peculiarity. In our experience, psoriasis is frequently met with in the tropics in Europeans and natives of every race.

Seborrhœic affections are common in the tropics, especially in Europeans. A *seborrhœide* of the chest is frequently met with, and often confused with ringworm. The microscopical examination will clear the diagnosis.

In Ceylon a peculiar form of seborrhœa capitis with yellowish scales is occasionally seen in European children between four and twelve years of age. This affection is probably due to *Pityrosporum cantliei* Castellani 1908, and quickly disappears when the child goes to cooler climates.

Dermatitis exfoliativa (pityriasis rubra) is not rarely met with, occasionally following on psoriasis. In Ceylon we have observed two cases in Sinhalese natives. The amount of desquamation was enormous. On removing the scales, which were white, the skin appeared of an angry red colour.

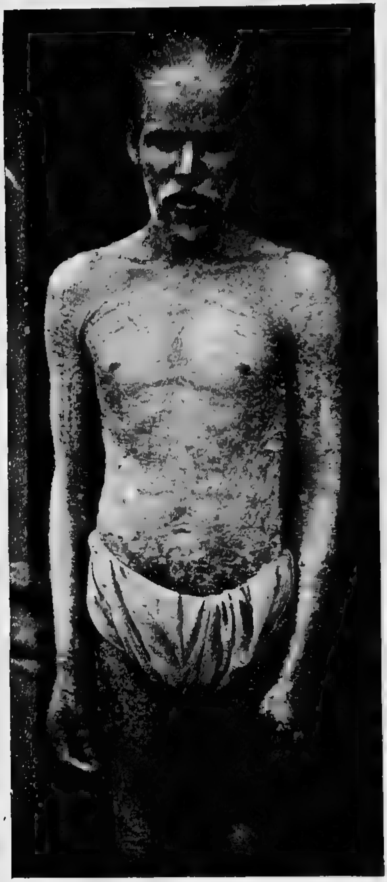

FIG. 370.—DERMATITIS EXFOLIATIVA IN A SINHALESE.

ACNE VULGARIS—ACNE ROSACEA—ACNE VARIOLIFORMIS—ACNE CHELOID.

Acne vulgaris and **Comedos** are extremely common in all races. Both types of acne—**Acne indurata** and **Acne papulosa et pustulosa** — are observed. The treatment, which is as difficult in the tropics as in temperate zones, is based on the use of medicated soaps and sulphur or ichthyol lotions. The vaccine treatment may give good results.

Acne rosacea is, in our experience, comparatively rare in the tropics, though we have seen cases in all races. True *rhinophyma* we have also observed.

Acne varioliformis.—This, in our experience, is as frequent in the tropics as in temperate zones, and may be found in all races. The regions of the body more commonly affected are the forehead, temples, the front of the sternum, and the interscapular region.

Acne cheloid is very common, especially among native races. The back of the neck is generally affected. Cases of *Acnitis* and *Folliclis* are occasionally seen.

HYPERIDROSIS AND BROMIDROSIS.

These conditions are, for climatic reasons, very common in the tropics. The treatment may be very difficult. Naphthol or salicylic-alcoholic lotions (1 per cent.), followed by a salicylic, boric, or tannoform powder, are useful. If there is much inflammation of the skin, no alcoholic lotions should be used, but simply water solutions of boric acid (2 per cent.), carbolic acid (½ per cent.), permanganate of potassium (1 in 5,000), and occasionally hydrargyrum perchloride (1 in 2,000 or 4,000), after which a salicylic or boric powder is applied. It should be always remembered to sprinkle with the same powder the socks and shoes and undergarments. Internal treatment by sulphur, acid drinks, etc., is not of much use. Belladonna and atropin will stop the secretion for a time, but they must be pushed till unpleasant symptoms occur. We have seen a case of *chromidrosis* of the axilla in a native boy due to the presence of a bacillus closely allied to the *Bacillus prodigiosus*.

Granulosis rubra nasi is not unfrequently seen in half-caste and European children.

LICHEN PLANUS—LICHEN SPINULOSUS—PITYRIASIS RUBRA PILARIS—PARAKERATOSIS VARIEGATA—POROKERATOSIS.

Lichen planus is common in the tropics among Europeans and natives of the various races. In very dark-skinned natives the diagnosis may be difficult to the medical man used to seeing skin diseases in Europeans only. Apart from the colour, however, the skin lesions are identical, the papules having an angular outline and a flat, occasionally umbellicated, shiny surface. When the eruption disappears, it generally leaves behind some pigmentation which is extremely well marked in natives. *Lichen natidus* has been seen by us on the penis of a half-caste.

Lichen spinulosus is occasionally met with in children.

Of **Pityriasis rubra pilaris** we have seen a case in a European.

TUMOURS OF THE SKIN.

The tumours met with in temperate zones are met with also in the tropics in Europeans as well as natives. There is no doubt, however, that native races are more subject to some classes of tumour than to others. We would call attention to the extreme frequency among the natives of cheloid and fibroma molluscum, and the comparative rarity of epithelioma of the face.

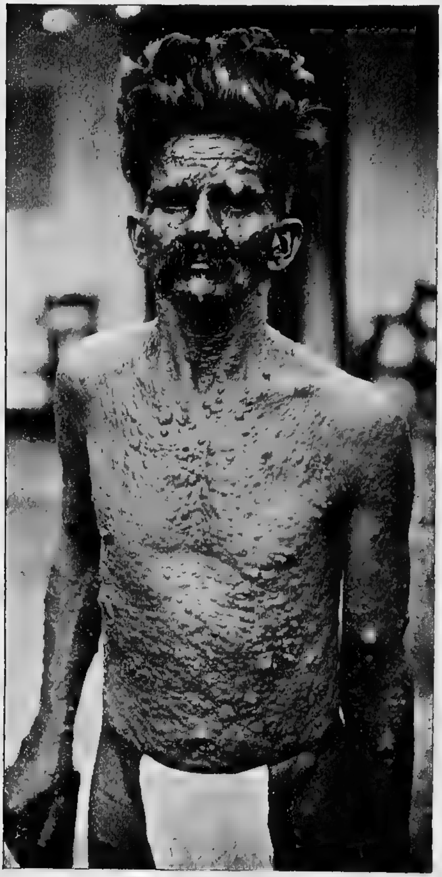

FIG. 371.—FIBROMA MOLLUSCUM IN A SINHALESE.

CONNECTIVE-TISSUE TUMOURS.

Benign Connective-Tissue Tumours.

Simple fibroma, Fibroma pendulum, and **Fibroma molluscum** (neurofibromatosis of Recklinghausen) are very frequently met with in natives. Myomata are occasionally observed — in our cases always on the face.

Angiomata are not rare, and **multiple Telangiectases** are fairly common, and **Lymphangiomata** very frequent.

Xanthoma planum and **Xanthoma tuberosum** are frequently observed.

Xanthoma diabeticorum is very common in India and Ceylon, where the better classes suffer greatly from diabetes. An example of Balzer's **Pseudo-Xanthoma** or **Elastorrhexis** affecting the abdomen was observed by us in a half-caste woman.

Cheloid.—This is extremely frequent in native races. According to some authors, negroes suffer from it sixteen to eighteen times as much as whites. In Indian races it is not so frequent as in African natives, but still, much more frequent than in Europeans. The smallest wounds, such as those made in tattooing, may be followed by cheloid. In Chinamen it often follows hypodermic injections of morphia.

Malignant Connective-Tissue Tumours.

Multiple sarcomatosis of the skin is rare. We have seen two cases, both in Sinhalese girls. Of the so-called **Lymphoderma perniciosa** we have also seen a case in a Sinhalese man.

Mycosis fungoides has been observed by us once only in a half-caste man.

EPITHELIAL TUMOURS.

Benign Epithelial Tumours.

Epithelial moles are frequently observed.

Molluscum contagiosum is met with in all races.

Verrucæ and **Warts** are extremely common. In two instances we have seen Sinhalese boys covered all over the body with hundreds of warts. *Filiform warts* are met with, and *gonorrhœal warts* are very common. *Verruca senilis* and *Verruca seborrhœica* are frequent.

Escomel has drawn attention to a peculiar treatment for warts in vogue among certain races in South America. These people apply the crushed body of a beetle belonging to the genus Meloe to the wart, the horny layer of which had been first scraped off. The wart disappears, leaving a slight whitish scar. The active principle is to be found in the beetle's blood.

Hyperkeratosis of the whole sole is often observed in natives going barefoot. We have seen several cases of *Cornu cutaneum;* in our cases the situation was on the hands.

Malignant Epithelial Tumours.

Rodent ulcer is comparatively rare among natives, but we have seen one case in a Sinhalese woman. We have observed a case of **Melanotic carcinoma** and two of Paget's disease of the nipple among half-castes.

MIXED TUMOURS.

Adenoma sebaceum of the face has been seen but rarely by us. We have never observed in the tropics cases of **Angiokeratoma** on the hands. The non-occurrence of this peculiar little tumour in the tropics is explained by the fact that this tumour develops as a sequel to very severe chilblains. We have, however, seen a somewhat similar tumour on the scrotum of a European.

RHINOSCLEROMA.

A case of rhinoscleroma has been observed by us in an Indian coolie, and Gros has reported the occurrence of the disease in

TUBERCULOSIS AND TUBERCULIDES.

Lupus vulgaris is met with in the tropics in all races, but, according to our observation, is far from being so common as in Europe.

Tuberculosis verrucosa cutis is very rare, and **Scrofulodermia** much less common than in temperate zones. All the so-called tuberculides —**Lichen scrofulosorum, Acne scrofulosorum, Bazin's Erythema induratum**—are observed but rarely in the tropics.

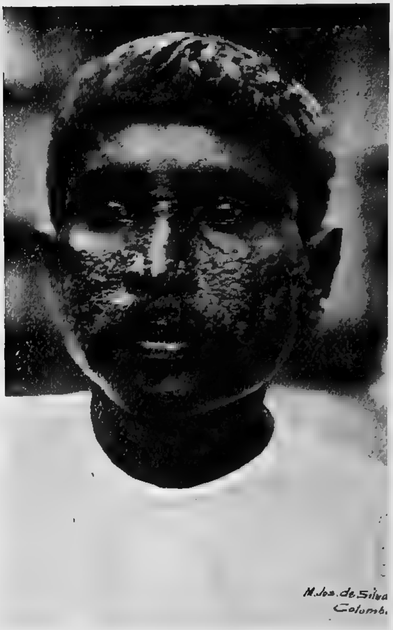

Fig. 372.—Lupus vulgaris in a Sinhalese.

Lupus erythematosus, as regards which we agree with those writers who do not consider it of tubercular origin, is very rare in the tropics.

SYPHILIS—VENEREAL SORES—BALANO-POSTHITIS.

At the present date syphilis is rampant all over the tropics. In the past there is reason to believe that it was unknown in many of those tropical regions which were unopened to the cosmopolitan trade. According to Lambkin, in some parts of Uganda syphilis affects more than half of the population, and this enormous diffusion of the malady has taken place during recent years since the country has been opened up. Syphilis is very common now also in all the other regions of Africa, and is very common in Tropical Asia. It has been noted by Fox that in America it is much more frequent among negroes than among whites. In our experience, the virulence, as well as the symptoms of the disease, are not much different from what one sees in Europe. We can, however, confirm Brauld's observation on the frequency of the primary sore on the suprapubic region of natives, who regularly shave their pubis. Perhaps the general enlargement of the lymphatic glands is more marked in natives, and circinate and pustular syphilides, as observed by H. Fox, are more common. The tertiary ulcerative lesions are apt to become of enormous proportions, owing to secondary infections, and to the patient not seeking proper medical advice for a long time. Of great interest is the fact that in uncivilized native races the so-called parasyphilitic affections (progressive paralysis and tabes dorsalis) are extremely rare.

As regards the treatment of syphilis in the tropics, inunctions are very unpleasant in a hot damp climate. We generally prefer the ordinary internal treatment by hydrargyrum cum cretâ, gr. i., three times daily. In severe cases we use injections of various preparations of mercury. Lambkin's cream is very useful. A mixed mercury and potassium iodide or mercury atoxyl treatment is of advantage in some cases. Natives are said by some authors to be extremely susceptible to mercury, but in our experience this has been exaggerated. We generally give them the same doses as to Europeans.

Venereal Sores.—These are common in all races, but are more apt to take a phagedænic character in the tropics.

Balano-posthitis.—Every type of balano-posthitis is met with in the tropics.

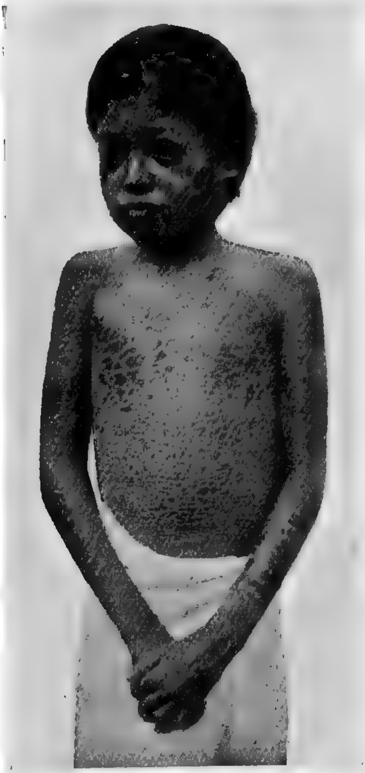

FIG. 373.—ICHTHYOSIS IN A SINHALESE.

ICHTHYOSIS—SCLERODERMIA—MORPHEA.

Every type of **Ichthyosis** is met with in the tropics, from simple **Xerodermia** to **Ichthyosis hystrix.** Diffuse sclerodermia is rare, but circumscribed sclerodermia (morphea) is rather frequent. We have seen a case of **Sclerema neonatorum** in a Sinhalese baby.

KAPOSI'S DISEASE—DARIER'S DISEASE—ACANTHOSIS NIGRICANS.

We have seen in the tropics several cases of **Kaposi's disease** (xerodermia pigmentosa) among European and half-caste children. We have not yet come across in the tropics cases of **Acanthosis nigra** nor **Darier's disease.**

LENTIGO—CHLOASMA.

Freckling cannot be seen in very dark-skinned natives, but is easily visible in half-castes. It is very common among Europeans, especially those who live an open-air life, and are much exposed to the sun.

Chloasma is a very common affection in the tropics, and is found among Europeans as well as natives. The dark-brownish or dirty-yellowish patches of chloasma are plainly distinguishable in the skin of Indian and Sinhalese natives, though in African negroes they may be indistinguishable. In Sinhalese male patients a condition characterized by two dark roundish chloasma patches situated symmetrically, one on each cheek, is very common. In some cases, in addition to these two patches, a third one is found on the nose. We have been often consulted by natives on this condition, as they greatly object to it. In Sinhalese women chloasma uterinum is very common. Several other forms of chloasma are observed:

1. *Chloasma solare* (*Melasma solare*), due to exposure to the sun. This is found among Europeans, half-castes, and also in natives. In natives who wear clothes it is easy to see that the parts exposed to the sun are darker.

2. *Chloasma caloricum*, from exposure to heat. Found often in stokers.

3. *Chloasma traumaticum*, from mechanical irritation, scratching, etc.

4. *Chloasma toxicum*, due to irritating drugs—as, for instance, after a blister.

5. *Chloasma malaricum and Kala-azar Chloasma.*—Patches of hyperpigmentation are found occasionally in patients suffering from chronic malaria, and in patients affected by kala-azar. A diffuse hyperpigmentation resembling Addison's disease has been described in the chapter on Malaria.

DISEASES OF THE HAIR AND NAILS.

The diseases of parasitic origin are common, and have been described. Cases of **Hypertrichosis** in man and woman are occasionally met with. The so-called 'fragilitas crinium,' as well as **Trichorrhexis nodosa**, are rare in natives, this being probably due to the habit they have of frequently oiling and greasing the hair. We have seen cases of **Moniliform hair** (monilithrix) in Sinhalese and Tamils. In several Sinhalese decrepit old men, who wear their hair long, and do not take care of it, we have seen a condition of inextricable matting of the hair somewhat resembling **Plica.**

Canities is said to take place at a later age in negroes than in Europeans, but in our experience neither in negroes nor in Indian races is there any distinct difference. **Alopecia** of every origin is met with in the tropics. **Alopecia seborrhoica** is very frequent among Europeans and educated natives. It is rare among the low classes. **Alopecia senilis** is less frequent in natives than in Europeans. **Alopecia areata** is apparently rare among natives, though fairly frequent among Europeans. We have seen a case of **pseudo-pelade** of Brocq (folliculitis decalvans) in a Sinhalese man.

All the diseases of the nails met with in temperate zones are found also in the tropics. We have noted with comparative frequency a form of onychogryphosis affecting several members of the same family, and apparently hereditary to a certain extent. The nails are enormously thickened, and much longer than usual. All the nails may be affected, both on the fingers and toes.

Onychomycosis of various origin is a common affection.

SOME COSMOPOLITAN DISEASES OF MUCOUS MEMBRANES.

Patches of **Leucoplakia** of the tongue are common in natives, and may be of various origin—syphilitic, frambœtic, or due to irritation caused by smoking or chewing various substances. **Lingua nigra** is occasionally seen. We have already called attention to the *dark patches* found on the tongue in natives, and which by some writers have been described as a sign of agchylostomiasis. A condition which might be called **red or purple tongue,** and which often puzzles the newly-arrived medical man, who does not know its origin, is extremely common in Ceylon among the coolies and lower-class natives, and is simply due to chewing betel. The pigmentation slowly disappears on the native discontinuing the use of betel. Cases of **furrowed tongue** (scrotal tongue) are not rare. We have seen a case of **Fordyce's disease** (pseudo-colloid of the lips) in a half-caste. A case of **Chelitis exfoliativa** in a European lady and cases of **perleche** have been observed by us among European children. Under the term *Ulcération saisonière récidivante des lèvres,* Gros has described a very superficial ulceration on the lower lips in Algerian natives which is very common in the hot season, and is apparently due to diplo-bacillus.

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THE END

Baillière, Tindall and Cox, 8, Henrietta Street, Covent Garden

PLATE I.

THE MALARIAL PARASITES.

Coloured by Leishman's Stain.

1*a*–4*a*. Plasmodium Malariæ.

- 1*a*. Young Trophozoite.
- 2*a*. Older Trophozoite.
- 3*a*. Schizont.
- 4*a*. Sporulation.

1*b*–8*b*. Plasmodium Vivax.

- 1*b*. Young Trophozoite.
- 2*b*. Older Trophozoite, showing Amœboid Movement.
- 3*b*. Schizont with single Chromatin Mass.
- 4*b*. Schizont with three Chromatin Masses.
- 5*b*. Sporulation.
- 6*b*. Young Sporont.
- 7*b*. Microgametocyte.
- 8*b*. Macrogametocyte.

1*c*–4*c*. Laverania Malariæ.

- 1*c*. Two Young Trophozoites.
- 2*c*. Sporulation.
- 3*c*. Macrogametocyte.
- 4*c*. Microgametocyte.